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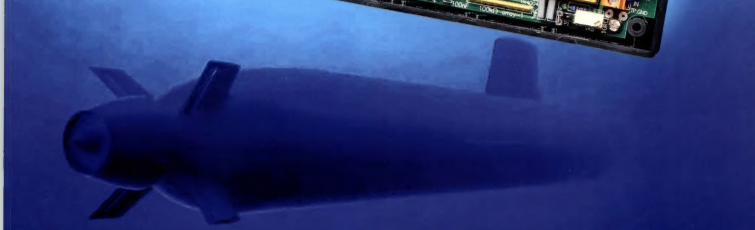

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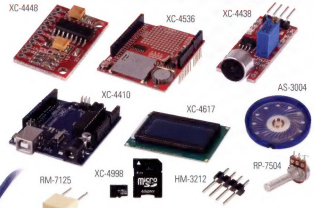

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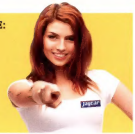

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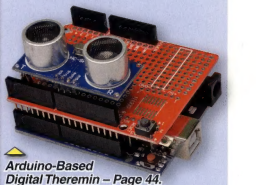

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SILICON CHIP
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SILICON CHIP is published 12 times a year by Silicon Chip Publications Pty Ltd. ACN 003 205 490. ABN 49 003 205 490. All material is copyright ©. No part of this publication may be reproduced without the written consent of the publisher.

Printing: Offset Alpine, Lidcombe, NSW.

Distribution: Network Distribution Company.

Subscription rates: $105.00 per year in Australia. For overseas rates, see our website or the subscriptions page in this issue.

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E-mail: silicon@siliconchip.com.au

ISSN 1030-2662

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Publisher's Letter

Controversial topics should be able to be discussed

Every time I write a Publisher's Letter or we have a feature article which is remotely related to the environment, I know that some people are not going to like it. Some may vehemently disagree. Some will go onto blogs and Facebook to accuse me of variously being a "climate denier", of not believing in "anthropological global warming", of being a rat-bag conservative who doesn't care about his grand-childrens' future or something more derogatory.

What I don't understand is why such people seem to take such personal affront and sometimes even go to the length of cancelling their magazine subscription or stating that they will never purchase the magazine again. Why don't they simply write in to disagree, together with references which show the error of my ways? After all, we do have a long record of publishing critical letters.

Or why don't readers who disagree so vehemently with the Publisher's Letter simply not just mutter an epithet, turn the page and then continue reading the stuff that they are interested in?

So I suppose some people will take affront at our feature article on Nuclear Submarines by Dr David Maddison, in this month's issue. I decided to commission the article partly because of its technical interest and partly because the recent decision to have a custom-designed diesel version of a nuclear submarine, which itself is not yet operational, will have serious ramifications for the Australian economy, for employment and for our national defence, for decades to come. Simply put, we probably won't have any submarines for quite a few years after the present Collins class is decommissioned.

If such a topic cannot be raised in a technical magazine, where else will it ever appear?

We should have nuclear submarines, regardless of where they are purchased and they should be an existing design. It is ludicrous to have diesel submarines for a country like Australia. They simply don't have enough range for Australia's huge coastline or for missions which could be expected to range for thousands of kilometres throughout south-east Asia.

Let's face it, most of our potential opponents in a future conflict already have nuclear submarines, so why shouldn't we? But if we go ahead with this decision, we won't have any subs, nuclear or otherwise, for some time. Maybe, just maybe, good sense will triumph but I am not hopeful.

Nor am I hopeful that this relentless rush to renewable energy might ultimately be tempered by the realisation that killing off coal-fired power stations will jeopardise the reliability of the entire Australian grid. The Hazelwood power station, which is not particularly old (it started operation in 1971) will be closed in four months. And other stations in the Latrobe Valley also seem to have an uncertain future. The Australian Energy Market Operator (AEMO) seems to think that the black coal-fired base load power stations in New South Wales will take up the slack but I don't think they are being sufficiently conservative. In future, much more extensive blackouts may occur and they could have really dire consequences.

I should state that I have written past Publisher's Letters on the undesirability of coal-fired power stations and the hazards of coal mining in general but I never considered that these stations might be closed without other base load stations, either closed-cycle gas turbine or nuclear powered, being built to still provide reliable base-load power.

I know that keen environmentalists put their faith in future developments of batteries or other storage systems to solve the intermittency of renewable energy sources. I hope that we have an article on that topic soon. Can you guess how that might turn out?

Leo Simpson

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MAILBAG

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Pacemakers are a hazard during cremation

I want to comment about the hazard of medical implants, as described in the article in the October 2016 issue. As a funeral director, I have to deal with pacemakers and defibrillators on a daily basis.

Before a person can be cremated, these implants have to be removed and a medical practitioner has to physically check to ensure that nothing has been missed. The reason for this is they can explode during the cremation process, with serious results. The influx of new devices posses a real risk in our profession. Anything containing a battery has to be removed but a lot of health professionals would not be aware of the new risks.

There is provision on a "cause of death" certificate for a doctor to state there is a cremation risk but usually these risks only apply to pacemakers and defibrillators, as no one has yet really looked at the situation.

We have fortunately found a couple of brain stimulators that were not noted on the doctor's certificate and removed them before any harm was done. When questioned, the doctor stated that he did not realize they posed a risk. As more and more various types of implants are used, there is a real risk of some one at a crematorium being seriously injured by a device exploding.

The whole implant industry needs to come up with guidelines in handling the disposal of their devices, and pass that information on to doctors and funeral homes.

John Arnfield,
Narangba, Qld.

Wind turbine role in SA blackout questioned

I read with interest your editorial in the November edition of SILICON CHIP. You state that "the wind blew just a bit too hard for their much-vaunted wind turbines and they all automatically feathered their blades to stop self-destruction". You also state that "after the blackout occurred a number of their spindly transmission towers then fell over".

I wonder if you have read the initial report on the blackout as published by the Australian Energy Market Operator. It is the best source of factual information I have found so far, and does not seem to have any bias for or against wind power built into it. It is entitled "A preliminary operating incident report for the national electricity market – information as at 9.00am, Monday 3 October 2016" and was published on 5 October 2016. It is available from **www.aemo.com.au**

It provides a minute-by-minute description of the sequence of events, and the following statement is from the Executive Summary of that document:

"The weather resulted in multiple transmission system faults. In the short time between 16:16 and 16:18, system faults included the loss of three major 275kV transmission lines north of Adelaide. Generation initially rode through the faults, but at 16:18, following an extensive number of faults in a short period, 315MW of wind generation disconnected (one group at 16:18:09, a second group at 16:18:15), also affecting the region north of Adelaide."

Further notes on Circuit Notebook contribution

Thank you for publishing my idea in Circuit Notebook, November 2016 ("Precision switched capacitor DAC needs no precision components") and for improving the clarity of my submission.

I would like to point out to readers that my submission consisted of only the skeleton of the idea, which included Fig.1 and Fig.2 and the descriptions that applied to them. SILICON CHIP staffers have fleshed it out to include Fig.3 and the associated text.

I'm happy that SILICON CHIP has edited and expanded my submission to improve it; the clarity of the description has been improved significantly compared to my submission, and adding extra switches to increase the output range of the circuit to include both 0V and Vref is an inspired idea.

As I was reading the text, it dawned on me that the fourth divider stage of Fig.1 (that was also present in my original submission) is unnecessary. This fourth divider stage has probably also led to some confusion in the text regarding whether Fig.1 represents a 3 or 4-bit DAC: it is in fact a 3-bit DAC.

Fig.3 does not repeat this error and is therefore a 4.1 bit DAC as stated. However, a small change renders IC8, D1 and D2 unnecessary.

For simplicity, I'll describe the change with reference to Fig.1. All that is required is to take Vout from the common terminal of the bottom half of S3. S3 now only needs to be an SPDT switch and the 4th divider stage is no longer needed. With this arrangement, Vout will vary from 0V to 7/8 * Vref in Vref / 8 steps as the digital input is varied from 0 to 7, making it unnecessary to subtract 1 from the digital input.

This rearrangement produces a 3-bit DAC with fewer components than previously required. If it is necessary for the output to range between 0V and Vref (making a 3.1 bit DAC), add a fourth SPDT switch, S0, that switches the output between Vref (when S0 is 1) and the common terminal of S3 (when S0 is 0).

Similar changes can be made to the circuit of Fig.3 to make a 4.1 bit binary DAC with glitch rejection.

Andrew Partridge,
Toowoomba, Qld.

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Mailbag: continued

Australian submarine decision is incomprehensible

In the Weekend Australian, October 29-30 2016, Rear Admiral Stephen Johnson (US Navy retired) claimed that, anyone who says that you can't put a diesel engine into a nuclear submarine design doesn't know what they are talking about. Mr Johnson now has the job as General Manager, Submarines, in the Australian Defence Department's Capability and Sustainment Group (CASG.) Of course he would say that.

He further claims that many aspects of the future diesel design, eg, cooling and generation systems, galley arrangements, hydraulic steering (etc) will be similar. He does not mention that over 22,000 pages of sensitive classified information on DCNS submarines have been leaked to the public allegedly by disgruntled ex-employees. So much for security!

Rear Admiral Greg Sammut, head of the Future Submarine program at CASG notes that, "it's a new design because no existing design meets our requirements" (echoes of the SeaSprite fiasco.) He also said, "it's going to take a period to get sufficient design maturity before we start construction."

But Australia cannot afford the luxury of a custom-designed submarine, because there is NO TIME to do this. By their public statements, the Defence Department have admitted that the design (even if they manage to fit a diesel engine to a nuclear sub) will take 15 years at least, including testing and evaluation.

By the best estimate the deeply flawed Collins class submarines will be completely worn out by 2025 and they may not even last that long. The decision to build a custom-designed submarine for Australia should have been made about 15 years ago. This would have been right in the middle of the SeaSprite custom helicopter fiasco and politically difficult. So they sat on their hands for 15 years. This is woefully delinquent.

We will now have a situation where, if the Defence Dept and their cronies have their way, we will be without a front line submarine fleet for at least 15 years. That's like owning a house in a dodgy neighbourhood without a front door.

The potential gap of up to 20 years in a front line submarine fleet is the massive consequence of the absolutely inept Dept of Defence.

Gary Johnston,
Submarines For Australia.
www.submarinesforaustralia.com.au

Nowhere in that document is there any suggestion that the wind farms caused the blackout. It does, however, state in no uncertain terms that the transmission line faults caused by the weather triggered the cascade of events that led to the blackout.

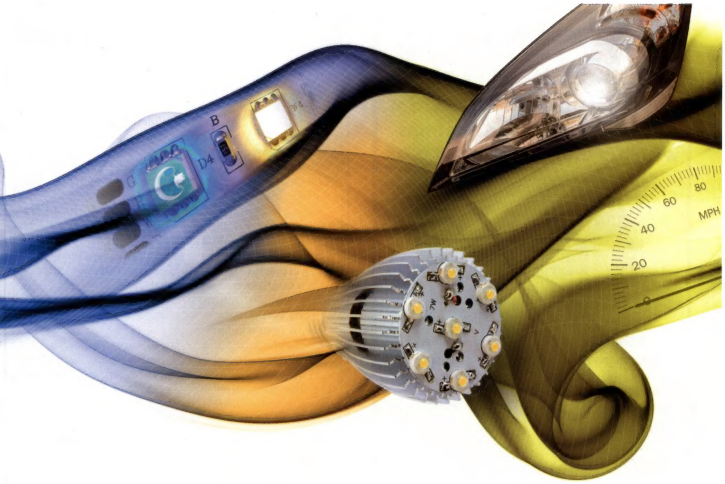
I have not yet seen any reliable information that suggests the wind farms caused the blackout. In fact, some wind farms stayed on line until the last of the thermal power stations tripped (page 10 of the above report, Table 3, at T=0).

I have not yet, despite repeated attempts, been able to find anything that reliably implicates the wind turbines as being the source of the blackout. I would be interested to know the source of your information about the wind turbines feathering in strong wind being the cause of the blackout.

Neil Biggar,
Perth, WA.

Leo replies: Since I wrote that editorial, more information has come to light which suggests that the wind turbines did cut out prematurely and that possibly their cut-out settings were too low. It is also clear that there were significant frequency changes (due to the wind turbines) which could have caused the interconnector to disconnect, even before the wind turbines cut out.

Interestingly, some of the sources which support my statements also refer to the AEMO report. For example, Joanne Nova analyses the report here:



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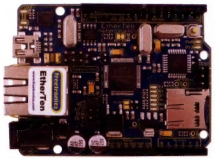

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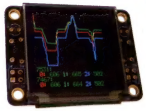

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Mailbag: continued

Current flow versus electron flow

In your October issue of SILICON CHIP, I was quite happily reading the article on the Micropower LED Flasher, until I got to Fig.2 which shows the charge/discharge paths of the timing/boost capacitor C1.

Why oh why in this day and age, have you found it necessary to still use "conventional" current flow? The charge/discharge paths clearly show the current flowing from + to - !

Being both an Avionics Technical Instructor in my day job and a volunteer Foundation/Standard/Advanced course instructor, the sheer thought of using conventional current paths astounds me! I hope your use of this outdated method to describe current flow was a mere aberration and that I will not see it again in any circuits in SILICON CHIP.

Greg Walker,
West Ipswich, Qld.

Comment: people have been arguing about this, virtually ever since electrons were discovered. In our defence, we use "conventional" current flow because it is the convention. Not even that most dogmatic of organisations, the IEC, have yet determined that conventional current flow must be abandoned.

http://joannenova.com.au/2016/10/sa-blackout-three-towers-six-windfarms-and-12-seconds/

There were also a number of articles in The Australian in the weeks after the blackout which provide evidence that the loss of wind generation was the final straw which took out the interconnector/disconnector by pushing it well over its design capacity.

Regardless of the exact sequence for the total state blackout, it seems likely that it would not have progressed to a total blackout if South Australia had its own base-load power stations operating and was not so dependent on the interconnector to the Victorian brown coal-fired base load power stations.

DAC circuit should have precision capacitors

Andrew Partridge's interesting article in the Circuit Notebook pages of the November 2016 issue, using a capacitor-based Kelvin-Varley divider in a DAC, does require precision capacitors to work accurately. If the paired capacitors are exactly equal in capacitance then the output voltage is exactly one-half of the input voltage. But if they are not equal when the capacitors are paralleled up and charge flows from the higher charged capacitor to the lower charged capacitor then while the resultant voltage will tend towards one half of the input voltage, it is not exactly one half if the two capacitors don't have equal value.

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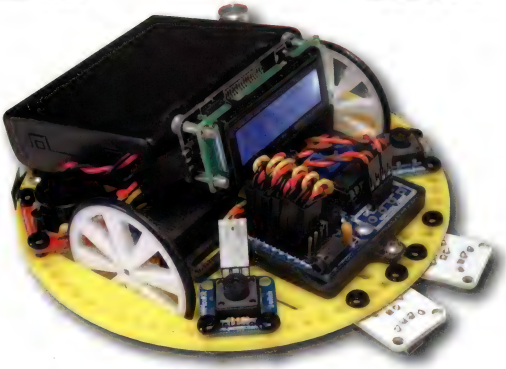

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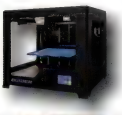

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Mailbag: continued

No need for a religious crusade against renewable energy

I always read the Publisher's Letter with interest whether it's on a technical topic or a flamboyant expression of opinion guaranteed to excite debate. May I join the flood of responses to the November 2016 editorial on the South Australian power blackout? I suspect this was written well in advance of the facts being known.

In fact the transmission line failures preceded the wind turbine shutdown. That radical greenie publication the Australian Financial Review reports the head of energy for Siemens Australia as saying, "The wind farms tripped off because of their proximity to the faults." "Whether it is coal-fired power or gas-fired power, either would be similar, and coal-fired power or gas-fired power are even more sensitive to low voltage or frequency faults than wind turbines." See www.afr.com/news/gas-plant-close-to-fault-would-switch-off-just-like-wind-siemens-20161019-gs6atu

There are many lessons to be learnt from the SA blackout, but a "religious crusade" against renewable energy is not one of them.

P.S. My mozzie lure from the October 2016 issue (night-time version) has yet to catch anything. I'm interested in other readers' results.

Peter Reed,
Fullarton, SA.

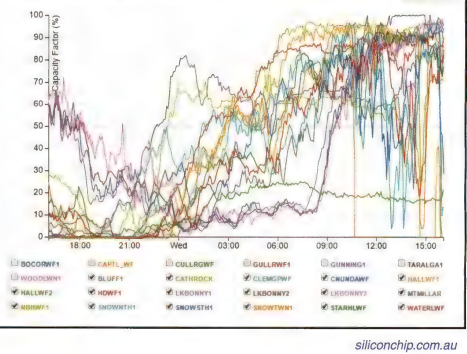
So for a 5% capacitor mismatch (C_1=1.05 times C_2), the voltage error is much less at 0.4%. Likewise, if the mismatch is 100% (C_1=2 times C_2), the error is 6%.

Ken Moxham,
Urrbrae, SA.

Wind power loss did cause South Australian blackout

Congratulations to Leo Simpson, (Publisher's Letter, November 2016), for his incisive analysis and statement of the consequences – the damage to the Australian economy, the ongoing train wreck that is the South Australian economy – of the state-wide blackout in South Australia on 28th September this year. The cause, for the grid collapse to propagate state-wide so quickly, was the sudden loss of some 315MW of wind generation in a 6-second interval, from 16:18:09 on 28th September (source: AEMO Preliminary Report - Black System Event in South Australia on 28 September 2016, page 2), available at www.aemo.com.au/Media-Centre/-/media/BE174B1732CB4B3ABB74BD507664B270.ashx

Predictably, there has been much finger-pointing, particularly by the renewables lobby, at the collapse of a number of key transmission lines during the severe weather event experienced across South Australia on the day. However, the fact remains that it takes much more than the few "system disturbances", that allegedly took out the wind farms, to take out conventional synchronous generation. In fact, a key statement of the AEMO



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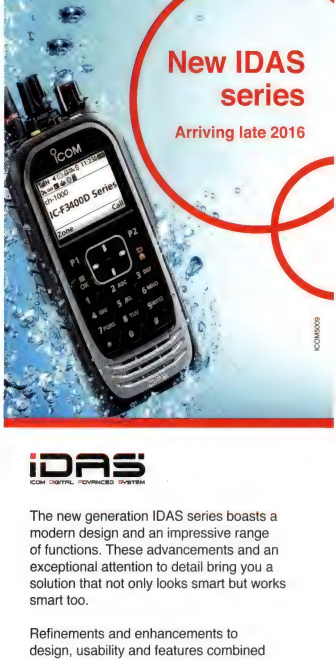

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Mailbag: continued

report is that, up until the loss of the Heywood interconnector, the State's synchronous thermal generation that was operational at the time continued to operate right up until the point of system collapse.

The role of the "system inertia", an inherent property of synchronous generation but absent in non-synchronous generation, such as wind farms and solar PV equipment, in enabling the riding out of the transients caused by system faults seems to be poorly understood by people other than power systems engineers.

Conventional generators, whether steam or gas turbine, diesel or hydro-powered can only be connected to the grid when their generator rotors spin at precisely what is called "synchronous speed". For a system frequency of 50Hz, as in Australia, the rotational speed of 2-pole alternator is 1500 RPM; for a 4-pole alternator, the synchronous speed is 750 RPM etc.

All conventional generators connected to a grid are spinning, in phase, at synchronous speed, actually providing the system frequency of 50Hz. The mechanical inertia of this collected rotation provides the "system inertia" of the grid.

It is the stored energy in this mechanical inertia that enables conventional generation to ride through system disturbances for periods that are long enough to change throttle settings, disconnect faulted lines etc, so as to deal with such disturbances as lightning strikes, transmission line faults, dropouts of large loads, and even failed generators. For a more complete explanation of the role of synchronous inertia, see, for example, Gannon, M. 2014 "Emerging Rate-of-Change-of-Frequency Problem in the NEM: Best-practice Regulatory Analysis of Options". Available at: **www.farrierswier.com.au/wp-content/uploads/2014/11/Best_practice_regulatory_analysis_of_emerging_RoCoF_problem_in_the_NEM_FSC.pdf**

In the days before the market distortion caused by renewables, the grid controller would ensure that all available thermal generation was powered up, in hot spinning reserve, so that in the event of system disturbances it was instantly available, ready to ride these disturbances out. In particular, all thermal generation near population centres would be fired up, ready to protect the grid in those regions.

In South Australia, there are two major power stations located within 20km of Adelaide: the 1280MW Torrens Island gas-fired steam plant and the 480MW Pelican Point state-of-the-art Combined Cycle Gas Turbine (CCGT) power station. One would have expected these to be fully operational in the lead-up to the onset of bad weather on the day. It is interesting to look at the state of preparedness in South Australia on September 28th last. From an analysis of the publicly-available AEMO data for Wednesday September 28th, two things stand out:

1. Some 600MW, comprising three 200MW generators, only, of the 1280MW capacity of the Torrens Island plant was actually operational. These generators were operating only at part-load, the balance of the requirement above that being supplied by wind generation and the Heywood interconnector from Victoria. One can only presume that this strategy was adopted because the power being sup-

plied via Heywood was cheaper than that from Torrens Island running on expensive gas.

2. The 480MW Pelican Point power station was powered off soon after midnight on the 27/28th and was non-operational right throughout the day, including the system collapse event, restarting only after about 10pm that evening.

3. The wind farms, particularly those in the mid-North of South Australia, were individually switching out and in, presumably shutting down in response to excessive local wind speeds, then restarting, with the result that their output was gyrating up and down through the course of the afternoon for some hours prior to the actual failure event. These power swings are a grid controller's nightmare.

It is clear that there was far less local synchronous generation than that being supplied by wind generation. The AEMO 5-minute data shows that when the critical loss of 315MW of wind generation occurred, both the Heywood interconnector and the operational local generation instantly responded, but clearly from the outcome, there simply was not enough generation available to make up that particular loss, particularly once the Heywood interconnector, which was supplying the bulk of the remaining power, tripped out.

For a more detailed analysis, the reader is referred to: **www.onlineopinion.com.au/view.asp?article=18577&page=0**

The accompanying plot of windfarm output before the blackout shows the large variations which occurred. It must be obvious now that having a large proportion of wind power in any grid is a formula for instability and ultimately, more state-wide blackouts.

There is of course no guarantee that there might have been a more favourable outcome, but South Australia would have been in a much better state of preparedness had the rest of the Torrens Island plant and that at Pelican Point been operational. Also, a major contributing factor to the blackout going Statewide was the closure of the 546MW Northern Power Station at Port Augusta in April.

Indeed, it simply beggars belief that the South Australian government permitted its closure. With the failure of the wind farms in the mid-North of the State and the loss of key transmission lines there, the entire northern region was effectively isolated. Had Northern still been operational, it is likely that the severe damage to both the Whyalla steelworks and the Port Pirie smelter might have at least been mitigated. Also, Port Lincoln might not have been without power for a week.

It beggars belief even more that the SA government would allow both the Torrens Island and Pelican Point power stations to be scheduled for closure in 2017, yet that was another proud boast some months ago. One can only hope that this recent event will bring sanity to bear.

It is also time that governments in Australia realised that messing with electricity grids is fraught with extreme risk. It is time they abolished the MRET subsidy scheme, as it is now clear that supporting intermittent renewable generation is a completely futile means of seeking to reduce CO_2 emissions.

Paul Miskelly,
Mittagong, NSW. SC

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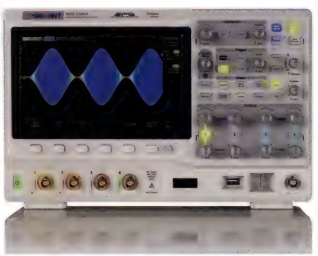

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NUCLEAR SUBMARINES

by Dr David Maddison

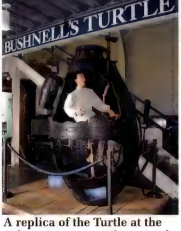
On April 26th this year, the Australian Government announced the $50 billion purchase of the next generation of 12 submarines, with the firm decision being made against the use of nuclear propulsion. Despite this decision, we now take a detailed look at nuclear submarines and their significant advantages compared to diesel-electric counterparts.

Before discussing nuclear submarines, we will briefly look at the history of submarines and the different methods of propulsion which have been used.

The idea of a submersible vessel such as a diving bell has been around for a very long time but the first vessels considered to be submarines were powered by hand-operated cranks driving propellers. A famous example was the Turtle, which was said to be used in 1776 in the US War of Independence to attempt to destroy an enemy ship, the HMS Eagle.

Arguably, there may have been no such attempt as there is no British record of the incident. However, it was the first submarine to be associated with a military use. The Turtle was not viable, though, as the operator quickly ran out of breathable air.

Then in 1863, the French Navy built the Plongeur which was powered by compressed air but this submarine was highly impractical and unmanageable.



A replica of the Turtle at the Submarine Force Library and Museum in Connecticut, USA, the first submarine associated with military use.

The next type of propulsion system was developed for the Spanish Navy by Narcis Monturiol in 1867. His "Ictineo II" used steam power on the surface and "air-independent" propulsion under water. The latter propulsion system used hydrogen peroxide which was decomposed, in contact with a catalyst, to generate oxygen and steam. This steam powered the propeller and the oxygen was breathed by the crew – a practical and ingenious approach.

With the development of the Whitehead torpedo in 1866 (mentioned in the September 2015 SILICON CHIP article on "Autonomous Underwater Vehicles"), the submarine also became a useful weapon.

(For more information on hydrogen per-

oxide as a fuel, see "Personal Flight Vehicles" in SILICON CHIP, August 2016.)

Next came the development of the British Resurgam in 1879. This was powered by a closed-cycle steam engine while on the surface. This engine could generate sufficient superheated steam while the vessel was on the surface to allow it to remain submerged and manoeuvre for up to four hours.

Before diving, the furnace was extinguished to avoid using the oxygen inside the submarine. But this submarine was not practical nor useful as the steam engine produced intense heat inside the vessel, as well as leaking fumes.

While the Resurgam was not a success, it did lead to the development of the series of Nordenfelt submarines, named after the Swedish industrialist who supported their development.

Like the Resurgam, they produced a reserve of pressurised steam on the surface which was later used for underwater propulsion. The Nordenfelt II (1886), III (1886) and IV (1887) each carried torpedoes.

The next major development was electric propulsion which required the development of suitable batteries. The first electric submarine was the Nautilus, built in 1886. Designed by Polish-Russian engineer Stefan Drzewiecki, it was 18m long, had a 9.7kW engine and 52 batteries but its development was discontinued after it became stuck in mud; a somewhat ignominious end.

This was followed by the Porpoise, designed in 1886 or 1887 by James Franklin Waddington in the UK. It had a battery of 45 2V 660Ah cells. This could power the vessel underwater for eight hours at seven knots (13km/h).

The Porpoise was equipped with two externally-mounted torpedoes and even though it performed well, Waddington was unable to get the Royal Navy interested in his futuristic craft and it sat anchored for two years. It was eventually broken up and Waddington went bankrupt.

Battery charging

A problem with purely electric submarines was that they needed to recharge the batteries without having to return to home port. The idea of recharging the battery on the surface via a petrol, kerosene or diesel powered engine came about around the beginning of the 20th century. This became the dominant form of submarine propulsion and this has been continuously developed ever since.

Initially, these submarines had to regularly resurface to charge their batteries and that made them vulnerable. The Dutch are credited with the invention of the snorkel between the two world wars to enable submarines to ingest air for their motor(s) to recharge their batteries while the bulk of the submarine remains submerged. With the use of radar for the detection of German U-boats at sea, the German navy retro-fitted snorkels to their submarines in order to avoid detection.

The Royal Navy tested snorkels but did not adopt the idea until *after* WWII.

Nuclear submarines

The next great development was nuclear propulsion, with the launching of the USS Nautilus in 1955. Nuclear propulsion offered the possibility of unlimited range, restricted only by the on-board food supply, maintenance requirements, atmosphere control and the mental ability of the crew to remain isolated, with no contact with the outside world.

Reactors on nuclear submarines generally do not need refuelling throughout their expected service life of 25 years or more. As an example, the US Virginia-class nuclear attack submarine does not need refuelling for 33 years.

Because of the high levels of power available on a nuclear submarine, they have very high top speeds and no restrictions on the "hotel" power loads which provide crew comfort such as unlimited hot showers, very clean air and so on.

The high speed and great range of nuclear submarines also mean they can escort naval convoys; conventional submarines are not fast enough to do this (at least, not when submerged).

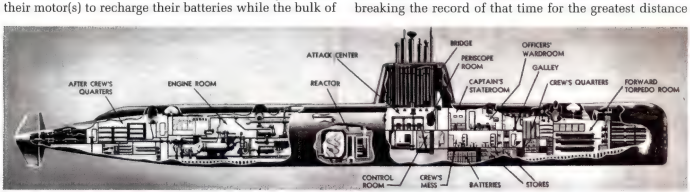
In contrast to the almost unlimited endurance of nuclear submarines, typical diesel-electric submarines might have submerged endurances of a few hours at top speed or a few days at slow speed. With air-independent propulsion or AIP (see panel), the submerged endurance of a non-nuclear submarine might extend, at slow speed, to as much as two weeks or a little more.

Nuclear submarine development

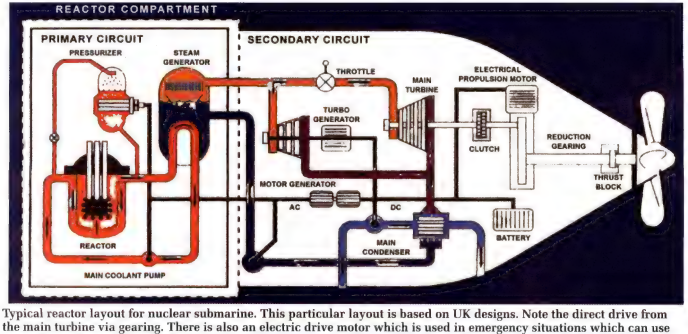
The idea of a nuclear submarine was proposed by the US Naval Research Laboratory and championed by Admiral Hyman Rickover. The US Government gave approval in 1951 and the first submarine was named USS Nautilus (SSN-571), after the submarine of the same name in the Jules Verne novel, "*Twenty Thousand Leagues Under the Sea*", written in 1870.

Nautilus took only 19 months to build from the time its keel was laid. It was powered by a purpose-built Westinghouse S2W pressurised water reactor which produced 10MW of power to propel the vessel.

On its maiden voyage, the Nautilus travelled 2,200km in less than 90 hours (faster than 13 knots or 24km/h), breaking the record of that time for the greatest distance



Internal view of USS Nautilus (SSN-571), the first nuclear-powered submarine, commissioned in 1954.



Typical reactor layout for nuclear submarine. This particular layout is based on UK designs. Note the direct drive from the main turbine via gearing. There is also an electric drive motor which is used in emergency situations which can use power from a battery if needed.

travelled underwater and the highest sustained speed of a submerged submarine.

Nautilus had a displacement of 3533 tonnes surfaced and 4092 tonnes submerged. It had a top speed of 23 knots (43km/h), was 98m long, had six torpedo tubes and a crew complement of 105.

By comparison, Australia's current Collins-class submarines have a displacement of 3100 tonnes surfaced and 3407 tonnes submerged, a maximum speed of 20 knots (37km/h) submerged, a length of 77m, six torpedo tubes and a crew complement of 58.

Because of the great sustained speed and endurance of the Nautilus, all existing techniques of anti-submarine warfare at the time were rendered obsolete. Nautilus was also the first vessel to travel to the geographic North Pole under the polar ice cap in 1958. This involved a difficult navigational problem because compasses don't work at those latitudes and the boat could not surface to take navigational measurements from the sun and stars.

The navigational problem was solved with the use of a modified inertial guidance system from a cruise missile. The main purpose of the mission to the Pole, apart from setting the record, was President Eisenhower's desire to demonstrate to the Soviets the capability to launch ballistic missiles from close to their territory.

The fascinating details of this journey and other material can be seen in the video link on the Nautilus.

Nuclear reactors in submarines

Submarine nuclear reactors fall into the category of small nuclear reactors, which by definition have a power output of less than about 300MW. The topic of small nuclear reactors was discussed in the June 2016 issue of Silicon Chip.

The US Virginia-class nuclear attack submarine (displacement 7800 tonnes, 115m long) has a reactor that can deliver 30MW of power to the main propulsor (which is effectively

Operation Ivy Bells

Operation Ivy Bells involved the use of a nuclear-powered submarine and a nuclear-powered eavesdropping device to tap into Soviet Navy communications that were carried on an undersea cable.

In the 1970s, the USA became aware of a submarine cable connecting a Soviet Navy base to the Soviet Pacific Fleet headquarters in Vladivostok. This cable ran through what the Soviets claimed as their territorial waters.

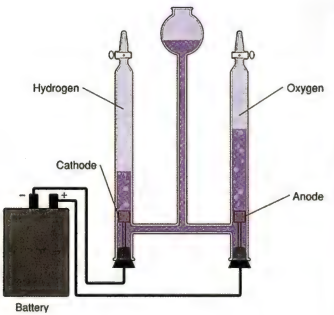
The US desired information running through this cable and so deployed the USS Halibut and deep sea divers working from the submarine in 120m of water to attach a recording device to the cable.

The device had no galvanic connection to the cable but could detect information running on the cable via inductive coupling. The listening device itself was nuclear-powered and was 7m long and weighed six tonnes. In the event that the Soviets ever pulled the cable up for repair, the device was designed to fall off so the Soviets would not find it.

The device recorded data on tape and every month, divers would return to change the tape. The Soviets did not suspect anything and had perfect confidence in the security of the cable as evidenced by the fact that communications were not encrypted.

This listening technique was so successful that many other such taps were installed at different Soviet cable locations and more advanced devices were developed that could store one year's worth of communications.

Eventually, the operation was compromised by an American agent with financial problems who sold the secret to the Soviets in 1980. Some time after that, US Navy divers returned to the site and discovered that the listening device had been removed.



(Above): basic "electrolysis" scheme by which electricity is used to separate and collect oxygen and hydrogen from water.

(Right): the Treadwell Corporation Low Pressure Electrolyser as used on some US Navy submarines to generate oxygen by the electrolysis of fresh water. Hydrogen that is also produced by the unit is discarded overboard or reacted in another process.

a ducted propeller). The largest nuclear submarine class ever built, the Soviet Typhoon class, had two 37MW steam turbines driving its propulsors, delivered from two 190MW (thermal) output reactors.

In contrast, the highly advanced air-independent propulsion system on non-nuclear submarines such as the German 212-class (displacement 1830 tonnes submerged, length 57m) has a main motor of 1700kW (ie, 1.7MW), a marine diesel engine with a power rating of 2150kW (2.15MW) and a type U32 fuel cell bank which can provide 240kW (0.24MW).

While the two types of submarine are not comparable in size or function, these figures show the huge difference in power. For example, when operating in AIP mode, the 212-class submarine uses the 240kW output of its fuel cells while the US Virginia class has up to 30,000kW available; 125 times more power for just over four times the displacement.

Reactors used in submarines have special requirements compared with land-based reactors. They must be corrosion-resistant against sea water, must have minimal vibration when operating, must be resistant to shock waves from explosions and they must not rely on gravity to drop control rods as the submarine may not be in an exactly vertical position.

Air Independent Propulsion

The possibility of air-independent propulsion (AIP) is often used to argue against the necessity for nuclear submarines, even though the range is still limited.

A conventional submarine has to surface regularly to run its (typically) diesel engine to recharge its batteries. Air-independent propulsion has been used as a method to get around this problem and enable a submarine to remain submerged for extended periods of time, giving it the advantage of some extra range, although nothing like that of a nuclear submarine. AIP has the possibility of being retrofitted into existing hulls.

AIP can be achieved by using liquid oxygen to provide oxygen to a closed-cycle diesel engine or alternatively, hydrogen peroxide which decomposes to yield oxygen and water. Both of these approaches have significant safety concerns.

Another type of AIP involves a closed-cycle steam turbine that burns ethanol and pressurised oxygen (at 60 atmospheres). This particular system is offered by a French company and can be retrofitted into some models of existing French submarines by, in one case, inserting an 8m long, 305-tonne "plug" or section to the hull of a submarine. This system gives an endurance of 21 days underwater.

AIP is also available by the use of a Stirling cycle engine using diesel and liquid oxygen, as fuel and oxidiser. In the Swedish Gotland-class submarines, a 75kW engine is used to run a generator to recharge batteries, giving a 14-day endurance at 9.3kph submerged.

Fuel cells have also been used for AIP with the use of ethanol and liquid oxygen. Siemens have a range of fuel cells from 30 to 120kW that have been used in some German submarines.

The Japanese Soryu-class submarine uses AIP with a Stirling engine and liquid oxygen but it has been suggested that later models may use lithium batteries instead, giving about the same range and much quieter operation.

The ultimate form of AIP is, of course, nuclear power.

Furthermore, as well as being compact and needing easy access to maintainable parts, due to limited space they must have a high power output per unit of volume and weight, and must be able to work when the submarine is accelerating, decelerating or turning.

Also, they must be able to vary their output power rapidly or shut down altogether. Finally, of course, they must be ultra-safe.

Due to the high level of power and required long fuel life, submarine reactors use uranium with a much higher enrichment level than used in civilian power reactors. So while a civilian power reactor typically has fuel with U235 content of around 3 to 5%, a typical military nuclear reactor's fuel has an enrichment level of 50 to 90%; the US Navy goes higher still and uses 96% U235 in its submarines.

The reactor is used to heat a fluid in its primary circuit, typically water under pressure, to a temperature of 250-300°C and this is used to heat water in another circuit, the secondary, via a heat exchanger. Two circuits are used so that radioactive byproducts which may leak from the fuel do not leave the reactor compartment.

American nuclear submarines use the secondary steam to drive a turbine which drives the propulsion system plus secondary equipment such as electrical generators. By contrast, in French and Chinese nuclear submarines, the steam turbine drives an alternator to produce power for the main electric drive motor.

Nuclear submarines usually have a battery bank for emergency use, a diesel engine to recharge it and an electric motor in the drive train so that the submarine can still move in the unlikely event of a reactor shut down. Because the battery bank is only for emergency use, it can be much smaller and lighter than in a conventional submarine.

Desalination on a nuclear submarine

Sea water is desalinated on a nuclear submarine and the fresh water produced is used for feed water for the steam generators, water for cooling equipment, drinking, cooking and personal hygiene and for electrolysis to generate oxygen for breathing.

Two processes can be used for desalination, reverse osmosis or vacuum evaporation/distillation. The latter is commonly used on nuclear submarines and the partial vacuum enables water to boil at a much lower temperature than is normal. The vacuum is produced by the main steam turbine's condenser and waste steam from the turbine is used as the heat source.

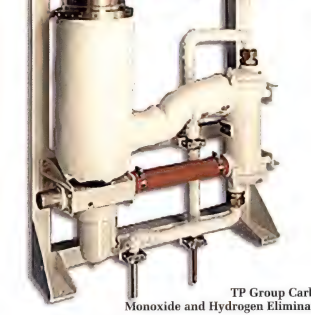
Atmospheric control

The main requirements for controlling the atmosphere in a nuclear submarine are oxygen generation, CO_2 removal (along with other contaminants) and maintenance of the correct humidity level to prevent condensation and for crew comfort.

We have touched on oxygen production and there are several electrolysis methods, all of which produce oxygen and hydrogen. In most cases, the hydrogen is pumped outside the hull but it can also be reacted with CO_2 from the scrubber to produce a liquid.

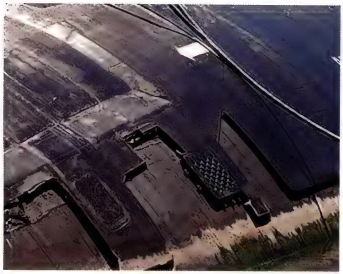
Carbon dioxide (CO_2) is removed from the submarine atmosphere by a process called scrubbing. The most common process involves passing the CO_2 through an aqueous solution of a strong organic base, known as MEA (monoethanol amine, $NH_2C_2H_4OH$). The MEA is then heated to drive off the solution which is compressed and pumped outside the hull.

Other gases that need to be controlled are carbon monoxide, which might originate from an accidental fire, frying

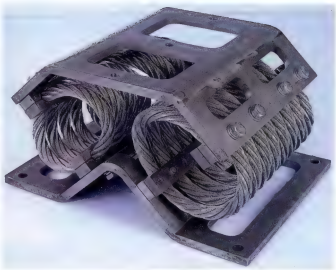


TP Group Carbon Monoxide and Hydrogen Eliminator.

Oxygen generators – a sealed can containing sodium chlorate to produce oxygen by chemical decomposition.



An example of tiles that have become detached from a nuclear submarine due to improper attachment. When attached correctly they are extremely difficult to remove.



A wire rope vibration isolator of the type used on a submarine. One side is bolted to the submarine hull and the other to equipment. This model is a GGG Series of anti-vibration mount by Wuxi Hongyuan Devflex Co., Ltd.

or combustion of engine emissions; and hydrogen, which may come from the emergency battery bank. These gases can be passed over a special catalyst to oxidise them to CO_2 and water, respectively.

Other undesirable gases can be eliminated with other types of catalytic reactor than that discussed above and also filtration through activated charcoal.

Noise and vibration

Modern submarines, no matter what their type, use rubber anechoic tiles on their hulls to reduce their acoustic signature, both reducing noise emanating from inside the submarine and also that reflected from incoming sonar signals.

Specific details of the tiles are a closely guarded secret so no pictures showing the construction of current tiles in use are available but there are many photos available which show what German tiles from WWII looked like.

The ideal tile would be perfectly lossy, work across all frequencies, work at all power levels and work at all operational depths of the submarine.

Tiles are typically made of rubber and are around 25mm thick which makes for a significant extra weight and they typically have a series of holes in them to establish a state of destructive interference to absorb sound waves.

New tile technology work has been published by a group led by Valentin Leroy at the Université Paris Diderot in France. They have produced a silicone tile just 0.23mm thick with internal cylinder-shaped cavities which are 0.013mm high and 0.024mm wide, separated by 0.050mm. Experiments in water showed that this material absorbed 97% of incident sound.

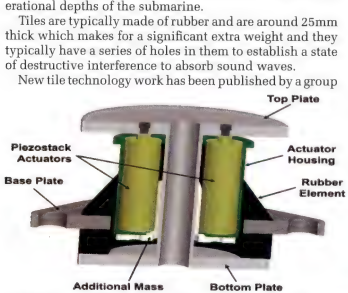
For this material to be useful for the sonar frequencies used to detect submarines, the material would need 2mm bubbles in a 4mm thick tile which in theory would attenuate incident sound waves by 10,000 times, 100 times better than previously thought possible.

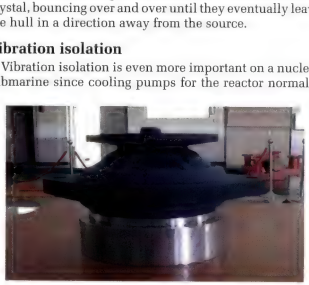
Another proposed (or possibly used) method to reduce the acoustic signatures of submarines involves the use of sound cancelling technology to transmit a sound wave of opposite phase of the sound to be cancelled – as in noise cancelling earphones.

Another proposed process is the use of a "phononic crystal" coating theorised by Baile Zhang Nanyang Technological University in Singapore, in which incoming waves bounce off the coating, are curved around and re-enter the crystal, bouncing over and over until they eventually leave the hull in a direction away from the source.

Vibration isolation

Vibration isolation is even more important on a nuclear submarine since cooling pumps for the reactor normally





Exploded view (left) and photo (right) of a mount with piezoelectric active vibration control

run continuously. However all submarines need to run air circulation and equipment cooling fans and anything that rotates or makes a noise needs to be silenced.

The specific details of vibration isolation in submarines are not usually published but the general techniques can be classified as either passive or active.

In passive systems, vibration is mitigated by either rubber pads or mechanical springs. In active systems, an electronic actuator, vibration sensors and a feedback circuit work together to cancel out vibrations by sending out-of-phase motion to generate destructive interference to cancel the vibrational mode detected, again, similar to the technique used in noise-cancelling headphones.

Active vibration control can also be used to reduce noise emanating from both the propeller and hull of either type of submarine.

A surprisingly simple but very effective passive vibration isolation system involves two plates connected by lengths of wire rope. This system can be used on the small scale such as with small cameras mounted on drones or on the large scale where it can be seen in videos of nuclear submarines.

For a practical demonstration of just how effective the wire rope can be, you can see an amateur application as used in a drone camera in the video: https://youtu.be/cajoxGhFQck

Note that while reactor cooling pumps normally run all the time, even when the reactor is idle, at times where maximum stealth is required, some reactors can have their coolant pumps shut down. They then rely on convection to circulate cooling water.

However this may only be possible for a limited time and even with the pumps shut down, the reactor may not be totally silent due to gas generation (bubbling) and so on. So any techniques which can prevent sound from the reactor core being heard outside the submarine are worthwhile.

Nuclear submarine types

Today there are two main types of nuclear submarines, attack and ballistic. Attack submarines have a similar purpose to conventional submarines and their functions include fending off enemy vessels which are trying to attack escorted vessels (aircraft carriers, troop transports, etc), attacking enemy vessels with torpedoes, attacking enemy land targets with cruise missiles, espionage operations including direct observation via periscope, listening into communications or sabotage operations with the insertion of commandos into enemy territory. An example of a nuclear attack submarine is the US Virginia class.

By contrast, the ballistic missile submarine is not designed to conduct combat operations but to act as an undetectable platform for the launch of submarine-launched ballistic missiles (SLBMs), which are typically (but not always) fitted with nuclear warheads.

There are also ballistic missile submarines which carry cruise missiles with conventional or nuclear warheads, or possibly a mix of both ballistic and cruise missiles.

In the case of US ballistic missile submarines, their location is so secret that not even the US Navy headquarters knows where they are at any given time. An example of a nuclear ballistic missile submarine is the US Ohio class. Submarines that carry SLBMs are used only by the major powers: US, Russia, UK, France and China.

Ohio-class ballistic missile submarine

Ohio-class submarines are designed to launch SLBMs and remain hidden for the duration of their missions. They displace 16,764 tonnes surfaced, 18,750 tonnes submerged and are 170m long. They are powered by an S8G reactor

Nuclear powered submarines versus conventional or AIP submarines

There are some fundamental operational differences between nuclear submarines and others with relation to their stealthiness and in particular their thermal and audio signatures.

Firstly, it has been said that nuclear submarines leave a thermal wake due to the need to continuously cool the reactor, which can, in theory, be used to detect them. However, in well over half a century of operation, no nuclear submarines are known to have been detected by this method, as at the depth they normally travel, the warm water would be quite dispersed by the time it reaches the surface.

Secondly, conventional submarines are reputed to be quieter and therefore harder to detect than nuclear submarines. The reason is that a nuclear submarine normally has cooling pumps running which make noise as well as steam noise when compared to a conventional submarine.

Of course, conventional submarines are only quiet when submerged; when they are surfaced or snorkelling they are running their diesel engines to recharge the batteries. Nuclear submarines are no noisier when surfaced than when submerged.

It is known with certainty that diesel submarines can be very quiet when submerged, as Australian submarines have been able to score "kills" on major US ships such as aircraft carriers during war games with the US Navy. What is not publicly known however is the true quietness of nuclear submarines. Given the success of nuclear submarines to date, it seems that the theoretical stealth advantage that conventional submarines might have over nuclear (when submerged) is unimportant in practice and has been dealt with by various noise suppression technologies.

In fact, in 2012, a Russian nuclear submarine sailed in international waters in the Gulf of Mexico, close to the USA, where it went undetected for several weeks despite expected US surveillance for submarines in the area so close to its shores.

Russia is now building nuclear submarines which are even more silent than those involved in this incident. See: www.siliconchip.com.au/l/aaaa

However, American nuclear submarines have been traditionally quieter than Soviet or Russian ones.

Also, the stealth advantages of conventional submarines would not apply when certain types of AIP are in use since it requires the running of a Stirling engine while submerged.

The real issue seems to be not that nuclear submarines are noisier than regular submarines but that all submarines are hard to find. In the marine environment finding a submarine is extremely difficult because of the huge number of noise sources, both natural and artificial.

Finding submarines very much comes down to the skill of sonar operators. It has been said that finding a submarine is like listening for a single car engine in a major city.

Also, passive sonar is normally used to search for submarines by other submarines. Active sonar, where "pings" are sent out, might be more effective but is not normally used because it discloses the position of the vessel emitting it.

Artist's concept of Cruise missile-converted Ohio class submarine launching Tomahawk missiles.

powering two turbines, each producing 45MW of propulsion power.

They are reported to be capable of 25 knots (46km/h) submerged and have an official test depth of 240m.

The main armament on the later version of the Ohio class is 24 Trident II D5 missiles, each of which can carry up to eight nuclear warheads with a 300-475 kiloton yield and with a range of 11,300km, along with a number of torpedoes.

After the end of the Cold War, four of these submarines were converted to launch a variety of different payloads apart from SLBMs. Examples of possible payloads include 154 Tomahawk cruise missiles, other supersonic or hypersonic cruise missiles, unmanned aerial vehicles (UAVs) and various intelligence-gathering sensors.

US Virginia-class submarine

The Virginia class are among the most advanced nuclear attack submarines in the Western world. They are designed for operation in shallow as well as deep water. They are expected to remain in service until as late as 2070.

These subs displace 7900 tonnes, are 115m long, have 30MW of propulsive power and have an official top speed of 25 knots although some sources say they can travel at up to 28 knots (52km/h) when submerged, or possibly higher.

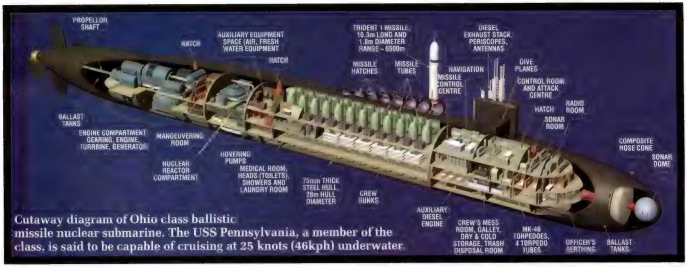
They have a test depth of 240m, a crew of 135 and depending on the version, can carry a combined 38 torpedoes and Tomahawk cruise missiles.

The Virginia class does not use a traditional periscope but has a number of masts for communications, radar, electronic warfare, snorkelling and photonics (ie, visual observation).

Unlike a traditional periscope that penetrates the hull and dictates the interior arrangement of the submarine, the photonics masts contain a variety of optical sensors and are connected with wires and optical fibres to the control room rather than a mechanical tube, enabling great flexibility in design as well as the rapid acquisition of data.

Because of the enormous power of a nuclear submarine, very careful attention has to be paid to the design of the propulsion system to avoid cavitation and the noise that it creates. Cavitation occurs when a propeller goes beyond a certain speed and bubbles (water vapour) form and cause noise when they collapse. The Virginia class uses pump jet

The photonics mast of a Virginia-class submarine.



Cutaway diagram of Ohio class ballistic missile nuclear submarine. The USS Pennsylvania, a member of the class, is said to be capable of cruising at 25 knots (46kph) underwater.

propulsion which is a type of ducted propeller, to minimise cavitation and other noise. No specific details are published but a picture is available of the pump jet propulsor of a US Seawolf-class submarine, which was cancelled before production due to excessive cost (See **www.bluebird-electric.net/submarines/submarine_pictures/USS-SeaWolf_fast_attack_submarine_stern_CAD_drawing.jpg**).

Later versions of the Virginia class have replaced 12 cruise missile launch tubes with two multi-purpose vertical Virginia Payload Tubes (VPTs) which can carry a variety of items such as Tomahawk cruise missiles, unmanned undersea vehicles (UUVs) or other types of weapons or equipment for specific missions.

From 2019, an additional section will be added to submarines under construction, adding a whole new 21m-long section with an additional four VPTs which will be the same diameter but taller than the other two.

Conclusion

So, as you may gather from the above, both nuclear-powered and conventional-powered submarines have distinct advantages. But it's the nuclear-powered types which have the distinct advantage on range, submerged speed, carrying capacity, power availability and various other parameters which arguably makes them the ultimate sea-based covert military platform. SC

Links, books and videos

"Questions asked of Australia's rejection of nuclear submarines" **http://siliconchip.com.au/l/aaab**

"The First Nuclear Submarine in The World" (About the USS Nautilus.) **https://youtu.be/FeVwEtmwOqg**

"The Untold Story of American Submarine Espionage: A Story of Heroes and Spies (1998)" **https://youtu.be/yIG4H3QOvH4**

"Blind Man's Bluff: The Untold Story Of American Submarine Espionage", Book by Sherry Sontag and Christopher Drew, 1998

"USS Virginia - The Virginia-class fast attack Submarine Fleet answering the Call of Duty to 2060" **https://youtu.be/_4mhcE2vPns**

"USS Pennsylvania Nuclear Submarine-HD Documentary" (About a ballistic missile submarine.) **https://youtu.be/TQLFMRAbOiU**

"The Largest Submarine in The U.S. Navy" (About a ballistic missile submarine.) **https://youtu.be/UxB11eAl-YE**

"Nuclear Depth Charge: Operation Wigwam Nuclear Test 1955 DOE, USAF Lookout Mountain" **https://youtu.be/7vR5n_arLwo**

AUTHOR'S NOTE: All information in this article was obtained from freely available public sources.

Two views of the Virginia class Ship Control Panel from where the boat is manouevered. The usual four crew positions of helmsman, planesman, chief of the watch and diving officer were combined so that two crew could perform all those roles from two workstations. These crew are called the pilot and co-pilot.

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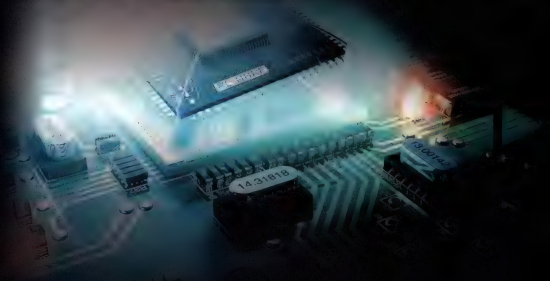

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Trick your car's ECU with this . . .

By John Clarke

Automotive Sensor Modifier

With this Automotive Sensor Modifier you can change the signal response of many of the sensors to improve your car's driveability, throttle response, handling and so on. It allows you to modify and program the response of any voltage sensor in your car, without prejudicing reliability or affecting the ECU in any way.

MODERN CARS have lots of sensors to closely monitor the engine and other systems and they provide information to the ECU (Engine Control Unit) which controls the fuel injectors and ignition timing, based on this information.

Some of the sensor outputs you can modify include the air flow meter, oxygen sensor, accelerometers (or G force sensors) used in stability control and traction control, and the throttle position sensor (TPS). For cars with an electronic (drive-by-wire) throttle rather than a throttle cable, modification of the TPS signal can literally transform the way the car drives.

For example, you can alter the TPS signal so that there is less pedal travel required to provide more throttle. This will make the car feel as though it has more power. And you can use this Modifier to restore correct air/fuel ratios after engine modifications, for preventing turbo boost cuts or to alter other sensor signals for improved driveability.

The Automotive Sensor Modifier is especially useful for adjusting a sensor output after engine modifications. The Modifier is then used to dial out the change in a sensor output due to the modification, to enable the engine to run correctly. In particular, various engine modifications or add-ons can cause a sensor output to go beyond the range normally expected by the ECU. This could cause it to issue an engine fault code that may result in the engine being set to run in limp-home mode. That means the engine and automatic transmission (if fitted) will be severely constrained until the fault code is cleared.

The Automotive Sensor Modifier takes a voltage signal and it can be programmed to produce a similar voltage at the output but which is shifted up or down in voltage level or changed in some other way. The programming is done using four pushbuttons in conjunction with a small LCD panel. Once the programming is done, the Modifier will do its job and the car will drive as you want it to.

In a little more detail, the input voltage from the sensor is divided into 256 different levels called load sites. Each load site can be independently programmed to alter the output by a set amount. The overall programming of all load sites is called a map. So as the sensor output changes in value, the output voltage from the Automotive Sensor Modifier will produce a modified voltage that follows the map.

Mapping is only one-dimensional, altering the output voltage according to a single input. This does have

limitations compared to having two inputs, where for example, mapping can be for voltage from a sensor against engine RPM. But a single dimension interceptor is effective in many cases when altering the response from a sensor such as an engine MAP (Manifold Absolute Pressure) or MAF (Mass Air Flow) sensor.

This Automotive Sensor Modifier is the third in a series of our popular voltage modifiers. The original Digital Fuel Adjuster (DFA) was featured in a 2004 SILICON CHIP publication titled "Performance Electronics for Cars". The second modifier was the Voltage Interceptor for Cars (described in SILICON CHIP, December 2009 and January 2010) which had a world-wide following by vehicle owners.

Specifically, the Voltage Interceptor for Cars has been successfully used to modify the MAF sensor output of the 3-litre Nissan Direct Injection diesel engine. When these engines have modifications and operate under certain driving situations, the MAF will produce out-of-range values. In response to these out-of-range values, the ECU sets the engine to run in limp-home mode. The Voltage Interceptor tricks the ECU into avoiding this.

However, all good things must come to an end (or be superseded) and since the kit for the Voltage Interceptor has now been discontinued, it was time for a new approach. This completely new Automotive Sensor Modifier is much simpler to build and does not require a separate hand controller. In addition, we have reduced the chip count to just two (compared to eight in the superseded design). And all controls and the LCD panel are on a single PCB.

Setting up is simple and it is also easy to transfer the adjustments of one Automotive Sensor Modifier to a second unit. This is most useful when building a second unit for an identical vehicle.

Features & Specifications

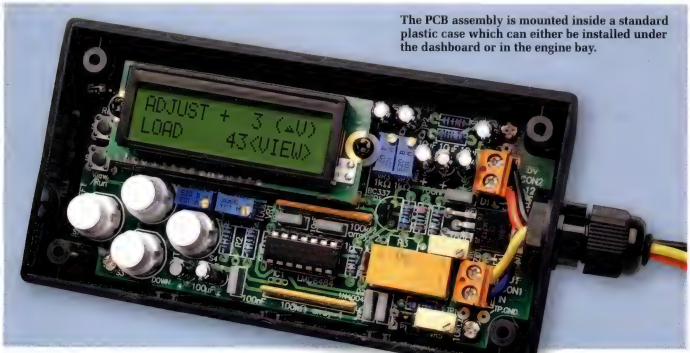
- Voltage input range: 0-5V
- Voltage output range: 0-5V
- Output adjustment: ±127 steps
- Output adjustment range: ±0.53V to ±5V (see Table 2)
- Adjustment resolution: 4.17mV to 39mV (see Table 2)
- Input adjustment points: 0-255 between the upper and lower input setting
- Upper input voltage limit: adjustable between 2.5V and 5V
- Lower input voltage limit: adjustable from 0V to the upper adjustment minus 2V
- Output adjustment response: typically 10ms to within 10% of the desired value
- Bypass relay: signal bypassed until the supply voltage rises by 0.5V from when power is first applied or the supply voltage exceeds 13.5V. Also switched by pressing the View/Run switch.
- Power Supply: 10-15V, 100mA

Features

An important feature of the Automotive Sensor Modifier is that when the map is set so that it produces no changes to the output, then the output exactly follows the input. That way, when you first connect the Modifier and before it is programmed, it will not affect the running of the vehicle in any way. Any subsequent changes introduced by programming the map values will smoothly alter the output.

Programming of the output mapping needs to be done with care and often in conjunction with equipment such as an air/fuel ratio meter to measure the effect of any changes. Adding in wildly varying values could cause error codes issued by the ECU or worse, engine damage.

The input to the Automotive Sensor Modifier can range from 0-5V but most sensors do not fully cover this voltage range. For example, a typical sen-



The PCB assembly is mounted inside a standard plastic case which can either be installed under the dashboard or in the engine bay.

Parts List

1 double sided, plated through PCB, code 05111161, 122 x 58.5mm
1 plastic case, 130 x 68 x 44mm
1 LCD module (Altronics Z7013, Jaycar QP5512)
4 pushbutton momentary contact switches (S1-S4) (Altronics S1099, Jaycar SP0723)
2 tactile switches (S5,S6) (Altronics S1120, Jaycar SP-0602)
1 DPDT 1-5A 12V relay, RLY1 (Jaycar SY-4059, Altronics S4150)
1 18-pin DIL IC socket
1 16-pin DIL IC socket (cut to form a 16-pin SIL socket for the LCD)
1 14-pin DIL IC socket (optional)
1 16-way SIL pin header
2 2-way pin headers, 2.54mm spacing (JP1 & JP2)
2 jumper shunts
1 cable gland for 3-6.5mm diameter cable
2 2-way screw terminal blocks, 5.08mm spacing (CON1,CON2)
4 M3 x 15mm tapped Nylon spacers
9 M3 x 6mm pan head screws
4 M3 x 6mm countersink head screws
2 M3 x 9mm tapped spacers (to mount LCD)
2 M3 Nylon washers (to mount LCD)
1 M3 nut
5 PC stakes (TP1-TP3, TP GND & TP5V)

Semiconductors

1 LMC6484AIN quad op amp (IC1)
1 PIC16F88-E/P microcontroller programmed with 0511116A.hex (IC2)
1 LM317T adjustable regulator (REG1)
1 BC337 NPN transistor (Q1)
1 16V 1W zener diode (ZD1)
2 1N0004 diodes (D1,D2)

Capacitors

5 100µF 16V electrolytic
3 10µF 16V electrolytic
4 100nF 63V MKT
2 10nF 63V MKT
1 1nF 63V MKT

Resistors (0.25W, 1%)

2 100kΩ 2% 10-pin SIL 5-resistor arrays (4610X-102-104LF) (RA1,RA2)
1 20kΩ 1 300Ω
1 10kΩ 1 150Ω
5 1kΩ 1 120Ω
1 390Ω 1W 1 10Ω
R1 – see Table 2

Trimpots

2 10kΩ multi-turn top-adjust trimpots (VR5,VR6)
2 1kΩ multi-turn top-adjust trimpots (VR2,VR3)
2 100Ω multi-turn top-adjust trimpots (VR1,VR4)

Where to buy parts

The PCB and programmed microcontroller for this design are available from the Silicon Chip Online Shop: www.siliconchip.com.au

sor output may only vary from 1.96V (minimum) to 4.65V (maximum). With the Modifier, you can set the input voltage range to be between the minimum and maximum sensor values. In doing this, a full 256 input load points are available for mapping.

The LCD shows both the current input load site number and the adjustment value that's set in the map. If there's no change, then the adjustment value for that load site is shown as 0. Changes to increase the output voltage are positive and changes to decrease the output voltage are negative.

Changes are made using the Up and Down switches, in one of two modes: (1) either in the Run mode (while the engine is running) as each load site is accessed in real time; or (2) in the View mode where the load sites are accessed using the Left and Right switches.

Circuit description

Fig.1 shows the circuit details. The two ICs used in the Automotive Sensor Modifier are a PIC16F88 microcontroller (IC2) and a quad op amp (IC1). The microcontroller monitors the sensor voltage and then produces a modified output according to the programmed map, in conjunction with quad op amp IC1. IC2 also monitors the switches and drives the LCD panel.

The sensor voltage is applied to the INPUT terminal of CON1 and then either directly through the normally closed relay contacts of RLY1a and RLY1b (when the relay is off) or in modified form via op amps IC1d-IC1a when the relay is switched on by the microcontroller.

The relay is included so that when the Automotive Sensor Modifier is first powered up (and when it's off), the input signal is bypassed around the Modifier circuit to the output. This is done so that the engine ECU will initially be directly connected to the sensor so as not to issue a fault code. This bypass mode allows the Modifier circuitry to start up and then produce the required output voltage.

IC2 monitors the battery voltage using a resistive divider at its AN4 input, pin 3. When power is first applied, it measures the voltage and stores the value. IC2 then continues to measure the voltage and when the supply reaches 0.5V above the stored value, the relay is switched on by IC2's RA6 output via transistor Q1 (the relay will also be switched on if the battery is above 13.5V). When the relay is on, the sensor signal is fed to op amp IC1d via an RC low pass filter comprising a 100kΩ resistor and 1nF capacitor.

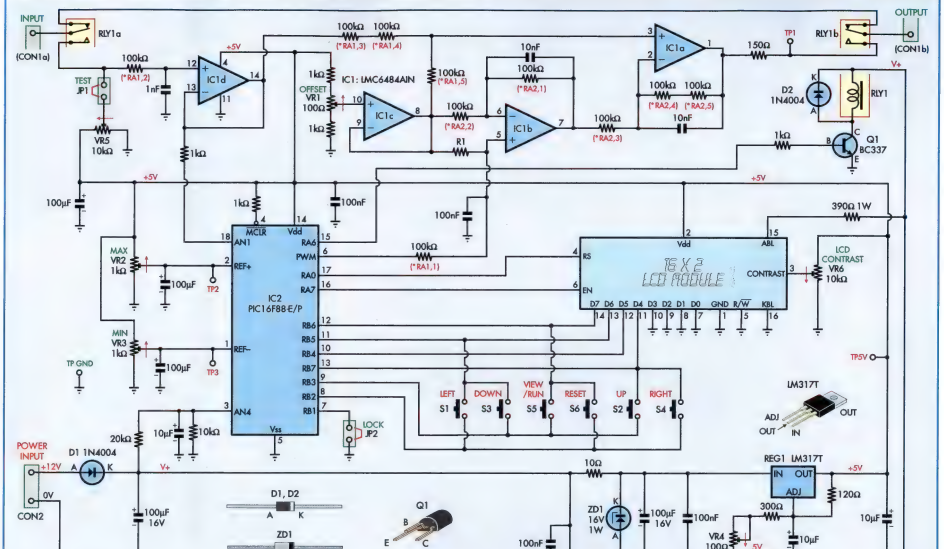
IC1d is configured as a unity gain buffer and its output is fed to the AN1 input (pin 18) of IC2 via a 1kΩ resistor. IC2 converts the voltage to an 8-bit digital value and each digital value becomes a separate load site ranging from 0-255. Each site can then be mapped for an altered output.

Note that there is also a jumper (JP1) that connects trimpot VR5 to provide a voltage which can be used instead of that from the sensor. This is used when setting up and testing the Automotive Sensor Modifier.

The voltage at the AN1 input is fed to IC2's internal ADC (analog-to-digital converter) and it has two references, REF+ and REF-, which are adjustable using trimpots VR2 and VR3.

There are limits in setting these two reference voltages. REF- can be set from 0V to 2V below REF+ while REF+ can be set between 2.5V and 5V. So for a sensor that has a 1.96V minimum and 4.65V maximum, REF- is set for 1.96V and REF+ set to 4.65V (these are within the voltage limit restrictions).

The next part of the circuit involving IC1c, IC1b and IC1a looks (and is) quite complicated but we can simplify it in



AUTOMOTIVE SENSOR MODIFIER

* RA1 & RA2 ARE EACH 5x100kΩ ARRAYS

Fig.1: the Automotive Sensor Modifier is based on PIC16F88-E/P microcontroller IC2 which has the ability to adjust a sensor's output at 256 points. The signal from the sensor is fed in via relay RLY1a, buffered by IC1d and fed to IC2's AN1 (pin 18) input. IC2 then produces a PWM signal at pin 6 which is then filtered and fed to IC1b to produce the programmed offset voltage. This is then fed to pin 2 of IC1a and then to the output terminal via relay RLY1b.

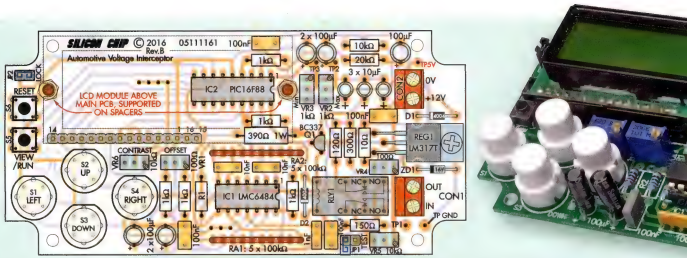


Fig.2: follow this parts layout diagram and the photo to build the PCB. The LCD module plugs into a 16-way pin header and is supported on two spacers. Make sure that all polarised parts are correctly orientated.

the following manner. Ignore IC1c and IC1b for the moment. Now the buffered output of IC1d is fed to an attenuator consisting of two series 100kΩ resistors and a shunt 100kΩ resistor. This attenuates the signal to one third the original level. The attenuated signal is then fed to op amp IC1a which has a gain of 3, to make up for the loss in the attenuator.

So why go to the bother of attenuating and then amplifying the signal to bring it back to the original amplitude? The signal needs to be attenuated so it can be level-shifted by op amp IC1b, in response to a filtered PWM signal from pin 6 of microcontroller IC2. Without the attenuation, the level shifted signal from IC1b would overload IC1a. Finally, IC1c is included to provide offset correction for the inevitable shifts caused by the signal manipulation.

The amount of level shifting performed by IC1b (as varied by the PWM signal) is set by the value of resistor R1 which effectively forms a divider with the 100kΩ PWM filter resistor.

When R1 is 100kΩ, the output can be shifted by up to 5V in either direction. This means that a 0V signal can be shifted up to +5V while a 5V level could be shifted down to 0V. There are some restrictions though. IC1a's output can only range from between 0V and 5V. So you won't be able to shift a 4V output to beyond 5V. Smaller ranges of adjustment are available by using lower R1 values and this also provides finer adjustment resolution. Table 2 shows the details.

Note that the red numbering used for the 100kΩ resistors around the op amps indicates two precision 5-resistor arrays. So, for example, the 100kΩ resistor between pins 8 & 6 of IC1 is RA2,2 (red), meaning that it is the second 100kΩ resistor in the second resistor array, RA2.

Power supply

An LM317T adjustable 3-terminal regulator, REG1, provides power for the LCD module, IC1 and IC2 and forreferences REF+ and REF-. A 10Ω resistor and zener diode ZD1 protect the regulator's input from excessive voltage. REG1 has resistors connected to its OUT and ADJ (adjust) terminals so that the output can be adjusted to an accurate 5V using trimpot VR4.

The LCD module is driven by IC2 via its RA0, RA7 and RB4-RB7 outputs. These outputs go to data inputs DB4-DB7 of the LCD module and to its enable (EN) and register select (RS) inputs.

Pushbutton switches are connected to IC2's RB5, RB6 & RB7 outputs. The RB2 & RB3 inputs are normally pulled high (to 5V) via internal pull-ups and if any switch is closed, then one of the RB2 or RB3 inputs will be pulled low via the closed switch contact.

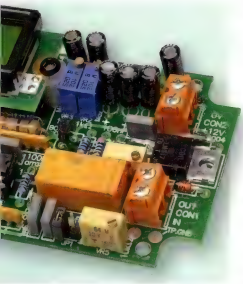
IC2 then checks to see which switch is closed. It does this by taking RB5, RB6 and RB7 low one at a time. The closed switch will show a low on either RB2 or RB3 when one of the RB5, RB6 and RB7 outputs is low. For example, when S1 is closed, the RB2 input will be low when RB5 is low.

Building it

Building the unit is straightforward

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	20kΩ	red black orange brown	red black black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	5	1kΩ	brown black red brown	brown black black brown brown
❑	1	390Ω	orange white brown brown	orange white black black brown
❑	1	300Ω	orange black brown brown	orange black black black brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	1	10Ω	brown black black brown	brown black black gold brown



since all parts, including the LCD, are mounted on a PCB coded 05111161 (122 x 58.5mm). The assembly is housed in a plastic utility case (130 x 68 x 44mm) and the switches and LCD are low enough for the lid to be attached without any clearance holes.

This means that the case is sufficiently sealed to keep dust and debris away from the PCB. It also means that any adjustments to the circuit must be done with the lid off but that's no great hardship since the adjustments are basically "set and forget".

Fig.2 shows the parts layout on the PCB. Begin the assembly by installing the resistors. Table 1 shows the resistor colour codes but a digital multimeter should also be used to check each value before it is soldered into place.

Diodes D1 & D2 (1N4004) can go in next, making sure they go in with the correct polarity. That done, install an 18-pin socket for IC2 with its notched end orientated as shown, then install IC1. The latter can either be directly soldered into place or mounted via a 14-pin socket.

Leave IC2 out of its socket for the time being; it's fitted later, after the supply rail has been checked.

Next, install 2-way pin headers for JP1 (bottom, right) & JP2 (top, left), then fit PC stakes to the five test points: TP1-TP3, TP GND & TP5V. The capacitors can then all go in. Note that the electrolytic types must all be orientated as shown on Fig.2.

Transistor Q1 (BC337) is next on the list, followed by regulator REG1. As shown, REG1 is mounted flat against the PCB with its leads bent down through 90° so that they go through their respective holes. The two outer leads will need to be bent down about 7mm from the regulator's body, while the centre lead is bent down some 5mm from the body.

Having bent the leads, drop REG1 into place and secure its metal tab to the PCB using an M3 x 6mm screw and M3 nut before soldering its leads. Note: the mounting screw can later be removed if it fouls the cable gland used to pass the external wiring connections when the PCB is later mounted in the case.

Trimpots & LCD header

Now for multi-turn trimpots VR1-VR6. VR1 & VR4 are both 100Ω trimpots and may be marked as 101, while VR2 & VR3 are 1kΩ types and may be marked as 102. Similarly, VR5 & VR6 are 10kΩ types and may be marked as 103. Be careful not to get the trimpots mixed up and be sure to install each one with its adjustment screw orientated as shown.

The single-in-line (SIL) 16-way pin header for the LCD module can now be installed on the PCB. Solder the two end pins first, then check that it's sitting flush against the PCB before soldering the remaining pins.

Once it's in place, mount a 16-way SIL socket on the underside of the LCD module (ie, with its pins soldered to the top of the module). This socket can be made by cutting a 16-pin (DIL16) IC socket in half lengthways and then mounting the two separate 8-pin sockets end-to-end on the LCD module.

Screw terminal blocks CON1 & CON2, relay RLY1 and the six switches can now be installed. Note that S1-S4 must be orientated as shown, with the flat edge of each switch towards the LCD module. S5 & S6 can be mounted on the PCB with the correct orientation only.

Installing IC2 & the LCD

Before installing microcontroller IC2 and the LCD module, it's necessary to accurately set the +5V rail. To do this, first apply power (12V DC) to CON2, then connect a multimeter between TP5V & TP GND and adjust trimpot VR4 for a 5.00V reading.

Now switch off and install IC2 in its socket. Make sure that its notched end is orientated as shown in Fig.2. The LCD module can then be installed by plugging it into the 16-way pin header and securing it to two M3 x 9mm tapped Nylon spacers, with a Nylon washer added to the top of each spacer.

Begin by securing the two M3 x 9mm spacers to the PCB using M3 x 6mm screws (see Fig.2). Do these screws up firmly, then plug the LCD module into the pin header, slide the two Nylon washers into place (ie, on top of the spacers) and secure the assembly using two more M3 x 6mm machine screws.

Fitting it in the case

The PCB is mounted inside the case on four M3 x 15mm tapped Nylon spacers. That's done by first using the PCB to mark out the mounting hole positions in the base, then drilling the holes to 3mm. It's best to use a 1mm pilot drill to start the holes, to ensure accuracy. The holes can then be enlarged to 3mm and countersunk using an oversize drill.

A hole is also required in one end of the case for the cable gland, positioned 12.5mm down from the top edge and centred horizontally. This hole should also be initially drilled to 3mm. It's then reamed out to around 12mm to accept the cable gland.

The PCB assembly can now be secured in position. First, attach the four spacers to the PCB using M3 x 6mm machine screws. The assembly can then be dropped into place and secured using four M3 x 6mm countersink head screws which pass up through the base.

Test & adjustment

Now for the test and adjustment procedure:

Step 1: apply power and check that characters appear on the display. If no characters initially appear, adjust contrast trimpot VR6 until characters do become visible.

Step 2: press and hold Reset switch S6 for four seconds until RESET is shown on the LCD. This resets the map, with all the adjustment values cleared to 0.

Step 3: install jumper JP1 and connect a multimeter between JP1 and TP GND. Adjust VR5 for a reading of 2.5V.

Step 4: connect the DMM between TP1 and TP GND and adjust VR1 so that TP1 is also at 2.5V.

Step 5: connect the DMM between JP1 and TP1 and adjust VR1 for a reading that's as close to 0V as possible, then remove JP1. Note: this adjustment sets the Automotive Sensor Modifier's output to follow the input.

Note also that any voltage applied

Table 2: Output Adjustment Range vs. Resistor R1

Adjustment Range	Adjustment Resolution	R1
±5V	39mV	100kΩ
±4.05V	31.9mV	68kΩ
±3V	23.6mV	43kΩ
±2.48V	19.5mV	33kΩ
±2V	15.7mV	24k
±1.3V	10.2mV	15kΩ
±1V	7.87mV	11kΩ
±0.697V	5.49mV	7.5kΩ
±0.53V	4.17mV	5.6kΩ

to the input cannot by altered until the relay is switched on. When the unit is installed in a vehicle, the relay switches on when the battery voltage rises after the engine has been started, ie, as the alternator begins charging.

However, if you are testing the unit with a fixed 12V supply, this feature may not be convenient. In that case, the relay can be switched on by pressing View/Run switch S5.

Using it

As stated earlier, the LCD lets you view the input load sites and the corresponding output change values, as set by pushbutton switches S1-S4.

On the top line, the LCD shows ADJUST followed the adjustment value and either (ΔV) or LOCK. The ΔV stands for "delta voltage" and indicates the voltage change made to the output. The bottom line shows the input load site.

The ADJUST value can be any number between -127 and +127 and is 0 when there is no change made to the output compared to the input. As previously stated, the voltage range depends on the value of resistor R1, as shown above in Table 2. This means that R1 also sets the adjustment resolution (or voltage steps).

If LOCK is displayed instead of (ΔV), it means that lock jumper link JP2 has been installed. This prevents any changes to the adjustment values using the pushbutton switches.

If BYPASS is shown instead of ADJUST, it means that the relay is not switched on and so the modified signal is not being fed through to the output. Instead, the input signal is directly connected to the output. As a result, when BYPASS is shown, the ΔV symbol is replaced with 0V to indicate that the output hasn't been changed by the programmed adjustment value.

The lower line of the display shows LOAD and then a number from 0-255. Following that is either /RUN/ or <VIEW>. The LOAD number shows the current load site which is one of 256 possible sites evenly spaced between the minimum and maximum input voltages. The displayed load site has the corresponding adjustment value shown on the top line.

The RUN display shows input load sites in real time as they follow any input voltage variation. You can observe each load site by adjusting trimpot VR5 (if jumper JP1 is fitted).

The VIEW display doesn't show the input load sites as they vary in real time. Instead, the input load site is selected by the Left and Right pushbutton switches (S1 & S4). This allows the entire load site map to be viewed (and altered) by scrolling through each value.

The display is switched between the RUN and VIEW modes by pressing the View/Run switch (S5).

Up & Down switches

The Up and Down switches (S2 & S3) are used to change the adjustment value for each load site. Each single press of an Up or Down switch increases or decreases the value by one step. Holding a switch down results in the value changing by about four steps per second. After five value changes, the values increase or decrease in steps of five.

The Left and Right buttons change the load site when in the VIEW mode. As with the Up/Down switches, the step rate increases when a switch is held closed. These switches do not operate in the RUN mode.

Pressing and holding the Reset switch (S6) for two seconds immediately clears all load site adjustment values to 0. The display briefly shows RESET on the top line when the reset occurs.

Adjustment

Before adjusting the unit, you first need to determine the voltage range produced by the sensor whose output you wish to modify. That can be done by connecting a multimeter to the sensor's output and checking the voltages produced under various driving conditions. This should include a wide range of throttle and engine load conditions. Get someone else to do the driving while you keep a record of the minimum and maximum voltages produced by the sensor.

Next, connect a multimeter between TP2 & TP GND and adjust VR2 for a reading equal to the sensor's maximum recorded voltage. That done, connect the multimeter between TP3 & TP GND and adjust VR3 for a reading equal to the sensor's minimum voltage.

There are a couple of things to watch out for here: (1) TP2 must be set somewhere between 2.5V and 5V; and (2) TP3 must be between 0V and 2V below TP2. This means that TP2 must be set to at least 2.5V, even if the sensor's maximum output is below this. TP3 then must be set so that it is at least 2V below TP2, even if this is below the sensor's minimum output.

Installation

Installing the Automotive Sensor Modifier is relatively straightforward, since there are just four external connections. Two of these are for power (+12V and chassis earth), while the other two "intercept" the sensor's output. The sensor's output is connected to the Modifier's CON1 input, while the output from CON1 is connected to the sensor's ECU wire.

Note that the original sensor-to-ECU connection has to be broken for the Modifier to intercept the signal, ie, the unit is installed in series with this lead.

Use automotive connectors for all wiring attachments and be sure to use automotive cable for the leads. The +12V rail for the unit should be derived from the switched side of the ignition and a suitable point can usually be found in the fusebox. **The connection to the switched ignition supply should be run to the Automotive Sensor Modifier via a 1A inline fuse. Use a circuit which is switched on by the ignition but does not drop out during cranking.**

An ELM327 OBD reader paired with an Android smart-phone or tablet can be used to help set up the unit. A WiFi version will be required to pair with an iPhone or iPad.

The best location to mount the unit is inside the cabin, so that it remains cool. If you do later install it in the engine bay, be sure to keep it well away from the engine and the exhaust system so that it is not unduly affected by heat. It can be secured in position using suitable brackets.

Programming adjustments

In order to make real-time adjustments, you first have to ensure that the mode is set to RUN. That's done by pressing switch S5. It's also important to remove the jumper shunt at JP1.

Note that any adjustments made will not take effect until the relay switches on and the word BYPASS is replaced by ADJUST on the LCD module.

Before going further though, a word of warning: using the Automotive Sensor Modifier could result in engine damage if the programming adjustments are not done carefully and methodically. You have been warned.

The best way to tune an engine using the unit is to set the car set up on a dynamometer and have a specialised engine tuner make the adjustments. Alternatively, you can make initial adjustments under actual driving conditions, using suitable instruments to monitor the performance. This is best done on a closed road, eg, a racetrack.

Be sure to get an assistant to drive the car for you while you make the programming adjustments and monitor the instruments. **On no account should you attempt to adjust the unit yourself while driving.**

An on-board diagnostics (OBDII) reader will enable you to monitor the performance. If you don't have one, you can purchase an ELM327 OBD reader cheaply on eBay, typically for less than $10 including postage. It plugs directly into your car's OBD socket (located near the steering column) and pairs with an Android smartphone via Bluetooth (a WiFi version of the ELM327 will be required to pair with an iPhone).

By installing a suitable app on the smart-phone (eg, Torque Lite for an Android device – **https://play.google.com/store/apps/details?id=org.prowl.torquefree&hl=en**), you can monitor various engine sensors and performance parameters, as well as check for (and clear) fault codes. Note that while modern cars use the standard OBDII reader format, some older vehicles may require a specialised reader.

Changes are made at the load sites as appropriate using the Up and Down buttons to assign values. Note that the load site values are likely to change while making adjustments. To minimise this, try to maintain constant engine conditions during programming. The unit locks onto the input value selected when an Up or Down button is pressed so that the input load site will not alter during an adjustment, so take care to ensure that you don't drift too far off the input load site by changing the engine conditions.

Releasing the Up or Down button will show the current load site. At this stage, it isn't necessary to access every input load site to make changes. However, you must keep a record of any sites that are actually assigned a value of 0, since these must be left at 0 when you later interpolate between the adjusted load site values – see below.

After mapping has been completed, you may find that you are using only a small range of adjustment values. In that case, try reducing the value of resistor R1. This results in larger adjustment values and increases the adjustment resolution. Of course, any changes to R1 will require a complete remapping of the load sites.

After making adjustments, there will inevitably be load sites that were not accessed and changed. This is because there could be up to 256 individual sites that may need adjustment and so only a representative number of sites are usually adjusted.

Interpolating the values

Switching to the VIEW mode lets you check your mapping. You should have already noted those sites which were mapped at 0. Any outputs that have

Running the Torque Lite app on an Android smart-phone paired with an ELM327 lets you monitor a wide range of engine parameters. This screen grab shows just some of the gauges that can be displayed.

a number other than 0 are obviously sites that were changed.

The job now is to make changes to the unmapped sites that sit between the adjusted sites. This involves interpolating the values so as to smooth out the changes between adjacent adjusted sites. Basically, it's just a matter of calculating the value of each step. That's done by dividing the difference between two adjusted sites by the number of unadjusted sites between them plus one.

As an example, Tables 3 & 4 show the initial mapped values and the result after manually interpolating the values. In Table 4, load sites 10, 11, 12 & 13 have values of 30, 0, 0 & 12 respectively. The difference between the two adjusted sites is 18 (ie, 30 - 12) and there are two unadjusted sites between them. In this case, we divide 18 by 3 (ie, 2 + 1) and this gives a step value of 6.

As a result, load sites 11 & 12 would be changed to 24 (30 - 6) and 18 (24 - 6) respectively, as shown in Table 5.

Similarly, for load sites 14-17, the output values are interpolated from an 8 at site 14 to a 0 at site 17. Note that site 17 was one that was mapped as a 0 and so this remains at 0. If the result of

Table 3: Mapped & Unmapped Values									
ΔV	30	0	0	12	8	0	0	0*	0
Load Site	10	11	12	13	14	15	16	17	18
0* = load site mapped at 0; 0 = load site left unmapped									

Table 3: initial values for load sites 10-18. The load sites with a value of 0 (ie, 11, 12, 15, 16 & 18) were left unmapped, while load site 17 was mapped at 0.

Table 4: Values After Interpolation									
ΔV	30	24	18	12	8	5	2	0	0
Load Site	10	11	12	13	14	15	16	17	18
Interpolated values shown in red – see text									

Table 4: the load site values after interpolation. The interpolated values are in red.

the divsion isn't a whole number, keep the decimal places and round the result for each load site to the nearest integer.

Finally, when mapping has been completed, the Lock jumper link can be installed on JP2 to prevent any further changes. If you are completely satisfied with the mapping, the LCD module can then be removed from the PCB.

Modifying sensor outputs

As stated, the unit can be used to modify any sensor that has an output ranging from 0-5V. In particular, this includes MAP and MAF sensors but an exception here is the Karman Vortex air flow sensor, as this produces an output frequency rather than a voltage.

Typically, you would use the unit to modify a sensor's output to improve engine response or performance, or simply to prevent engine fault codes occurring. You will need a separate unit for each sensor you wish to modify.

Most of the time, an engine runs in what is called "closed loop". This is where the MAF (or MAP) sensor and the oxygen sensors are monitored so that the correct amount of fuel is delivered to the engine via the injectors.

In operation, the oxygen sensor acts as a feedback sensor to let the ECU know whether the engine is running rich or lean. This means that it's possible to make changes to a sensor's output but then find that there's no change in engine response. That's because the ECU is receiving feedback from the oxygen sensor and adjusts the injector signal accordingly to provide the air/fuel ratio required.

Basically, the ECU has a set of maps for each engine sensor and for the throttle position sensor and the injectors. These are just tables of expected sensor outputs against engine RPM, temperature, load and mixture. When the engine is running, the ECU compares the sensor maps against the actual sensor values. However, over time, the ECU makes some changes to the map (called trims) that are based on real-time engine running.

OK, let's take a look at some of the changes you can make:

(1) Changing The Oxygen Sensor Signal: when an oxygen sensor is working correctly, it will provide the ECU with accurate air/fuel ratios. The ECU then modifies the injector duty cycle to match the oxygen sensor's signal and the signals from other sensors, to give the desired air/fuel ratio.

It's unlikely that a narrowband oxygen sensor signal can be successfully modified, mainly because the sensor signal appears more like a switch, as it produces a sharp change in voltage between lean and rich air/fuel ratios about stoichiometric. The output of a wideband oxygen sensor is also difficult to modify, because the sensor's expected output is determined internally by the ECU.

Note that a faulty oxygen sensor will be flagged if the injector and MAF (or MAP) sensor maps fail to correlate with the oxygen sensor's signal. This means that if you make changes to the output that go beyond what is expected by the ECU, then an error code will be issued. This not only applies to the oxygen sensor but to other sensors as well.

(2) Changing Air/Fuel Mixtures: as well as operating in closed loop mode, many engines also operate in open loop mode under some conditions, during which the oxygen sensor is not monitored. This usually occurs at or near full throttle when the mixture is made richer to provide extra engine cooling. Adjusting a sensor output, such as from a MAF, will result in mixture changes under such conditions, with corresponding changes to engine performance.

You will need to make before and after modification measurements to ensure that the engine will not be running too lean or rich. If the mixture is set too lean, the engine could run too hot and damage the valves and pistons. Conversely, running an engine too rich can foul spark plugs, damage catalytic converters and cause pollution.

(3) Reducing Turbo Boost Cuts: another possible use of the unit is to restrict the MAF (or MAP) sensor's output under high loads to prevent turbo boost cut. You will need a boost gauge to correctly carry out this modification.

It's just a matter of using the unit to alter the MAF's signal so that the ECU no longer reduces the boost above certain engine loads. By using the boost gauge, the load points where the boost is cut can be determined and the output from the Sensor Modifier reduced to eliminate the boost cut as required.

(4) Throttle Position Sensor (TPS): electronic or drive-by-wire throttles (as distinct from cable-operated throttles) can be modified to alter the way a vehicle responds to throttle changes. This can radically change the way the car drives.

Using the unit to increase the throttle voltage at low-throttle positions can make the engine appear to have better response, especially from a standing start. Conversely, on more powerful vehicles, reducing the throttle voltage at low-throttle positions can make the vehicle more docile. This could be especially helpful when moving off in slippery conditions, where wheel-spin could otherwise easily occur.

(5) Injector Changes: when larger than standard injectors are fitted, the unit can be used to reduce the air flow meter's output so that the correct the air/fuel mixture ratios are maintained. Reducing the air flow meter's output will thus allow the ECU to operate within its normal range of input values, so that it can control the injector duty cycle and maintain correct mixtures.

(6) Air flow Meter Changes: installing a larger air flow meter results in lower air flow readings compared to the original unit. The Sensor Modifier can be used to restore the signal to the normal range of values expected by the ECU.

Finally, when you have completed mapping, don't forget to install the Lock jumper link at JP2. SC

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Looking for a little different gift idea this Christmas?

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Last month, we talked about the IoT (Internet of Things) and how it is already a major influence in all our lives, even if we didn't (or don't yet) know it. Then a couple of IoT application adverts started appearing in just about every internet page I opened – so much so that I started wondering if they were even remotely as good as they claimed. . .

The first, and major product was a tracking device called (surprise, surprise!) TrackR. There are several models of TrackR but the one getting the most attention was the TrackR Bravo.

After reading glowing report after glowing report (and even seeing some videos on YouTube, etc) we decided to get a couple of these devices and give them the SILICON CHIP treatment.

After all, if they were as good as they claimed/seemed, a lot of readers would be interested in them as Christmas presents. They were certainly cheap enough!

by Ross Tester

OK, what is a TrackR Bravo?

As we mentioned, it's a tracking device for . . . anything! They've been attached to all manner of "things" such as wallets, briefcases, purses, mobile phones (although there's a bit of a catch-22 there!), pushbikes, keys, cars, boats, lawn mowers, tablets and notebooks,

Showing the four colours of TrackR Bravo close to life size (actual diameter is 31mm), the unit is supplied with a small keyring and a double-sided adhesive tab, so you can attach it to just about anything. There is also a smaller, thinner "TrackR Sticker" available, which at 25mm diameter is more suited to smaller, thinner items such as wallets.

snowboards and skis, clothing, skateboards, expensive toys, luggage – in fact, there is very little that they can't be attached to. There are even waterproof cases available!

And while TrackR don't recommend it, (they say to use GPS tracking devices) we've seen stories about them being placed on kids and pets (in case they wander off). That also raises the possibility of older people too, especially those suffering dementia in its various forms.

That's half the story – so just how are they tracked? Here's where it gets really interesting!

There are two ways TrackRs are tracked. I guess you could describe them as "local" and "remote".

First, the local, is intended for all those things you misplace around the home, office, etc.

This is via an app on your smartphone – Android (4.4 and up) or iPhone (8.0 and up), which then pings the TrackR via Bluetooth 4.0 LE (more on that anon) with a range of up to about 30m. If the TrackR is still within range, all that happens is that its location is displayed on a map. If the two become separated (ie, the TrackR has absconded!), your phone lets you know. So if you accidentally leave your wallet in a store, you won't get far before you are notified.

Fortunately, you can turn this feature off, for example, when you're home – otherwise you'd go mad every time you moved outside the TrackR's range.

What's the most-often-lost item in the home? The TV remote control, of course. Stick a TrackR on it and if it hasn't gone walkabout (eg, off to work in dad's pocket!) and the TrackR is within range, the smartphone app will not only sound a buzzer on the TrackR to help you locate it but also tell you if you're getting close (remember the old game – cold, warmer, hot, super hot – it works the same way).

But even better, it works in reverse too – press a button on the TrackR and your smartphone will ring to tell you where it is hiding!

What if you lose both your smartphone and TrackR? That's the Catch-22 we mentioned earlier. The phone will know where the TrackR is (millimetres away!) but you won't – because you've lost your phone!

Disadvantages?

There are two disadvantages we see with this short-range tracking. First, having to keep Bluetooth turned on: many phones are notorious battery users with Bluetooth on, so it's wise to keep that in mind.

Second, the TrackR "beep" is very soft and would really only be good indoors. In their specs, TrackR maintain the beep is "up to 92dB" (that's about the noise level of a truck!) but we believe it was much less than this.

Competing against traffic noise or even normal city noise, we don't believe it would have a hope!

Crowd tracking

The second method of tracking objects (the "remote" tracking) is really neat, even if (at the moment) a little optimistic here in Australia.

It relies on someone with TrackR enabled on their smartphone walking, driving or otherwise being within the 10m range of the TrackR. It then sends a "last known location" to the cloud, while the app on your phone tells you the TrackR's "Last Known Location", so you can attempt to find it yourself by going there.

Of course, the missing item (with TrackR) might be moving or have been moved elsewhere by the time you get to its last known location. In this case, you're reliant on someone else moving into range.

So that remote control that Dad inadvertently got on the train with this morning may well have passed close to several TrackR users in his travels, and TrackR will report its last known position.

TrackR maintain they have over 3.5 million devices already in the field but the majority of these would be in the home of TrackR, the USA.

My phone kept on insisting there were 3,377 TrackR users "nearby" (no, they didn't narrow that down!). But strangely enough, that figure never changed so we are inclined to take that with a chunk of salt, which is just a bit bigger than a grain . . .

We believe you'd have to be pretty lucky to have enough users here in Australia for this feature to work really well – yet. But as more and more TrackRs come on line (and as we said earlier, they're doing an enormous amount of

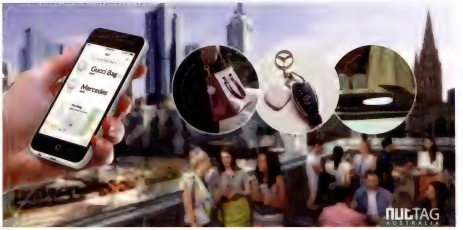
TrackR Bravo isn't waterproof but is more than happy being used in a spray-protected area – such as under this pushbike seat. It's held in place with the double-sided adhesive pad supplied. TrackR could also help you find your stolen car, used in a similar way. And it might also help you find where you parked it in the shopping centre carpark, too!

advertising) as well as offering some very good multiple deals, (such as buy three, get five or even buy four, get four free) this could easily change even in the short term.

With Christmas only a few weeks away, we'd imagine that a lot of people will buy multiple TrackRs and keep some but give others to relatives, friends etc.

There's a video (claimed to be based on a true story) of a pushbike being stolen in California and the owner using the crowd GPS function to go to its last known location, then finding the stolen bike in someone's yard.

Incidentally, we went to the official TrackR website in the US to get our TrackR – if you Google "Trackr Australia" you will come up with "TrackR Australia Official". With a URL of **www.thetrackr.co** (*not* **.com.au**), we think it just might be somewhere else!



We included this graphic from NutTag mainly to show the logo at bottom right: it clearly says NutTag Australia which implies (but doesn't guarantee) that NutTag does have a local "presence" and therefore warranty, service etc *may* be easier.

Similar products

We would be very remiss if we didn't mention that TrackR isn't the only device of this type available. (It was the only one we tested, though).

You might see others advertised – in particular the NutTag (**www.nuttag.com.au**) and the Tile (**www.thetileapp.com**).

Less commonly, in Australia at least, you might come across the PROTAG Duet, the LassoTag, the Tintag and Find'Em Tracking. All work in a similar way using Bluetooth LE (low energy).

The beauty of any of these trackers is that they SHOULD work anywhere in the world. Certainly the local tracking will work; we're only assuming that the distance (crowd) tracking should also work overseas.

The NutTag has had a limited amount of publicity but essentially does the same things as the TrackR – although (of course!) NutTag claim it does it much better.

Unlike TrackR, they appear to have an Australian presence which should mean better local service and support. Similar to TrackR, the NutTag has a replaceable battery.

Other NutTag features include: Geo-Fence feature, real-time GPS tracking for friends, four weeks historical GPS footprints, one year battery life, 50 meter range, separation alert on phone app and tracker (ensures you never lose your phone or your keys with just one NutTag.)

The other tracker mentioned, the TILE, is somewhat similar to the TrackR but with one important difference – unlike both the TrackR and NutTag, the TILE battery is not replaceable, so after a year (estimated battery life) you either have to buy a new TILE (at $US25 each) or take advantage of the "ReTILE" service which allows you to swap your dead TILE for a new one at 50% off.

Their website says that in Australia, JB HiFi, Harvey Norman and the Apple store sell the TILE but we don't know if they are going to offer the ReTILE option. We've also seen other local sources online but have no experience with them.

The TILE does have a couple of advantages that the others don't: being sealed, it's water resistant (to IP5 standard) – so a shower of rain won't worry it. It's not water PROOF – you can't attach it to your scuba tanks, for example. But you can attach it to Tessie's collar (as seen overleaf) and have a reasonable expectation that it will keep working.

The TILE comes in two sizes – a miniscule 34 x 34 x 4.65mm, 6.1g model to attach to keys, pets, bikes . . . anything . . . and the TILE Slim which is 54 x 54 x just 2.4mm; designed to fit in your wallet (it's about the thickness of two credit cards).

And a postscript: while researching trackers of various types, we noted that the TILE emerged as the victor in various tests, both in range – around 40m separation compared to half this for most of the others and also in hearing range.

At left are four colours of the NutTag, while at right are the two sizes of The TILE (TILE Mate and TILE Slim). Both work in similar ways to the TrackR – indeed, The TILE seems to get better reviews. Its big disadvantage is that it doesn't have a user-replaceable battery, unlike the TrackR and NutTag. However, this makes it more water resistant than its competition.

A common criticism of most trackers is the distance away you can hear them. The TILE was consistently the best at 30m or so with the others ranging down to almost zero, particularly when they had to compete against traffic noise or even background noise outside.

Practical tests

We only had the TrackR to try out but you can read plenty of tests online.

We were using a recent Android smartphone, so after loading the app from Google Play and installing it, we made sure Bluetooth was turned on then opened the TrackR app.

To select the TrackR, it's simply a matter of pressing the small button on it (under the TrackR logo) and then selected the "Wallet" icon. The final step was to register the TrackR so it would receive the crowd GPS updates (what we called "remote mode" earlier).

The phone then started searching for the TrackR – which it found easily when the TrackR disc was only a short distance away from the phone.

And that's what it told me – my imaginary wallet was "very close". I could make it beep if I wanted to, to assist tracking it down.

I moved the TrackR about three metres away and told it to search again. This time it reported that my "wallet" was "far away" (which of course it wasn't!) but I could easily track it down.

Moving the "wallet" even further away proved no difficulty for the app, until I moved outside the range (which was considerably less than the 30m claimed – I'd estimate less than half that).

Time for a wallet holiday

OK, that proved that the "local" tracking worked, so I sent the wallet on a cross-country jaunt.

One of our staff members lives about 50km from the SILICON CHIP office so I gave my imaginary wallet to him and asked him to keep it where it could be "seen" (ie, by others running TrackR app) as he drove home on Friday.

My app changed to the screen similar to that shown below right . . . and stayed that way for the weekend. This was despite the TrackR tag being driven around at the weekend and then back to work on Monday.

The car is now partked only about 15m away (admittedly through three brick walls) but I would have expected the tag to be found by now. It hasn't been!

So it has to be said, the crowd GPS updates are not yet perfect – NYP, as my boss used to say.

I mentioned earlier that I thought the expectations of this working in Sydney during such early days of the TrackR were pretty much wishful thinking – I'm sure it will stay that way until there are rather more users so it has a much better chance of being tracked.

This is despite the app telling me, still, that there are 3377 users in my area. That figure never changes!

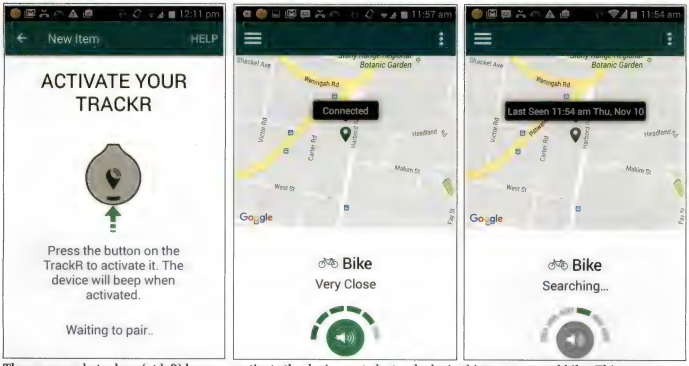
Recommended?

Given my experience, would I recommend TrackR, (or any other of the tracking devices we've looked at here)?

The answer is a guarded "yes", if only because of what they promise as they become more popular.

Already they're great for finding lost or missing objects around the home of office. Just think how many times you have misplaced YOUR wallet, keys, etc!

And as the number of users increases (and I suspect rather dramatically some time on or after the 25th of this month – call it a premonition, if you like), I'm sure the crowd GPS function will really come into its own. SC



These screen shots show (at left) how you activate the device up to be tracked – in this case, my pushbike. This comes up every time you enter a new TrackR. The centre screen shows what to expect when you're in the local mode – it tells me I'm very close to the elusive bike (close enough to trip over!). I can tell the TrackR to sound an alarm (OK, it's more a squeak!) so I can find it. The right-hand screen shows the device when it's in the "crowd-GPS" mode (ie, not local – it's well and truly lost!) but in this case it couldn't find the bike. Hopefully that will all change shortly.

Another "different" gift idea this Christmas?

Anti-Card-Skimming Devices

This has absolutely nothing to do with TrackR, Bluetooth LE or any of the other technologies we've been talking about in this feature. But we thought we'd make mention of an Australian device which does exactly the opposite – it stops communication!

You'd have to be aware of the reports on the news of "skimming" or "sniffing" devices used by crooks (I was going to use a much stronger word!) to read information stored on your credit or debit card – with the sole function of stealing your card information and so steal from you.

Until fairly recently, these low-lifes made and fitted false fronts to ATMs etc so that any card used could be read – they even had a camera to record the password as it was entered.

With the advent of smart credit/debit cards and "Paypass", "PayWave" or "Tap&Go" technology, they don't even have to go that far (besides, they're too easy to discover). All they need do is walk within 10m (some say 30m) of you and a small transmitter/receiver they carry in their pocket or back-pack interrogates any card in your wallet or purse – and the RFID chip in the card (which you can't turn off) freely sends back the information they're after.

Sounds far-fetched? It's happening right now – and it could happen to you! There are plans on the internet (or at least the dark net) to build such devices for a little over $100. A thief could skim a hundred times that in a day's "work".

While most of the credit card data is encrypted, the card number and expiry date are generally not. You've seen the reports on the news about visitors to Australia being caught with hundreds/thousands of blank cards – they're only blank until written with YOUR data!

What the crooks are basically doing is "cloning" your credit card – they use a cheap card writer to put your details into one of the blank cards. Then with a reasonable guess at the store "floor limit" they use that card in a cashless transaction, perhaps dozens of times in a day – all charged to your card!

Many people don't even check their credit/debit card statements, or if they do, just look for obvious charges they don't recognise. When reported to the bank, they're usually reversed after proving they aren't yours.

Arguably the best value we've found is this 10-pack of RFID Blocking Card Sleeves, available on ebay for $6.85 including postage! The company selling these is Superb Seller and the item number (at press time) is 222061269676 – otherwise, search for "RFID Blocking Card Sleeve".

But if your card statement shows some very low value transactions that you don't recognise and you'd normally ignore, say $1 or $2, talk to your bank immediately because this may suggest a thief has skimmed you and is just doing dummy runs to make sure it works.

To make matters worse, once they have your identity they can then go online and start collecting bits and pieces of information about you – how many people wished you happy birthday on Facebook, for example.

There is so much information freely given away every day it's scary – and it's what the crooks are relying on.

The object is to eventually have enough data to establish your identity so they can apply online for a loan of, perhaps, $10,000 or $20,000 in your name – which you know nothing about.

This is called identity takeover – and there have been countless cases of it occurring already in Australia. Countless? The banks never give the true numbers but various estimates put identity takeover and the fraud which goes with it in the hundreds of thousands, if not millions, of cases each year. That accounts for billions of dollars.

And if this hasn't scared you enough, the same techniques are being used to skim information from ePassports and even NFC-enabled smartphones.

The RFID Blocking Sleeves (left) and the RFID Wallet (right) are two of a number of card and passport protection products from a Queensland charity, Scanguard. They also sell anti-theft bags, aluminium cases and luggage locks. The best part: all profits are donated to charity. They will accept your order via credit/debit card – and a twin pack of RFID blocking sleeves costs just $8.95 plus postage. The five pack as shown is $14.95. The blocking wallets range from $29.95 to $79.95 with free delivery within Australia on selected products. View the product range and order via their website: www.scanguard.com.au

Another offering, this time from Scan Blocker, is said to be an active device which is triggered (and powered) by the scammer's RFID interrogator. Instead of simply blocking the signal, as the other types shown on this page do, this creates an E-field around your cards making them invisible to the sniffer. It also scrambles the sniffer's signal. Active types are more expensive than passive – this retails for $59.95 but there is a buy one, get one free offer. It is marketed online by Global Shop Direct. www.globalshopdirect.com.au (search for scan blocker).

Now you can fight back!

There's been a whole industry set up in retaliation to credit card theft. They're mainly intended to stop the RFID scanners talked about above.

For example, on ebay there are any number of Anti-skimming Wallets and card holders for around $20.00 or so. Or there are individual sleeves into which you slide your card – with the same effect. They're blocking the transmission of information from your card by electronically shielding it.

There are also "active" protectors which emit a 13.56MHz frequency to electronically jam the NFC (near-field-communication) signals that NFC-enabled smartphones and cards use.

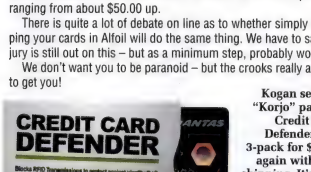
We saw a demonstration of one of these devices recently where the card was waved over a pay-wave terminal – and naturally, the terminal recognised it. But placed inside either the card sleeve, wallet or active protector, no amount of passing, waving or tapping would allow it to be read. If it works this well close-up on a terminal, it should make your card, phone or passport totally secure.

Just remember that the RFID interrogater used by a scammer (from a distance) would have to be a LOT more powerful than that used in a merchant's terminal.

Sleeves are available on line – priced at less than $1.00 to about $20.00; wallets a little more. Active blockers are more expensive, ranging from about $50.00 up.

There is quite a lot of debate on line as to whether simply wrapping your cards in Alfoil will do the same thing. We have to say the jury is still out on this – but as a minimum step, probably worth it!

We don't want you to be paranoid – but the crooks really are out to get you! SC



Kogan sell the "Korjo" passive Credit Card Defender in a 3-pack for $9.00, again with free shipping. It's said to block both 13.56MHz and 860-960MHz scammer's signals.

See www.kogan.com – search for credit card defender.

What is Bluetooth LE?

The Bluetooth standard has been around for a while now. It is yet another method of wireless data communication, in many ways similar to WiFi, Zigbee etc. In fact, Bluetooth shares the same frequency band – 2.400-2.4835GHz. Data is split into packets and exchanged through one of 79 designated Bluetooth channels (each of which have 1MHz bandwidth).

Bluetooth suffered from one major problem, however: because it was designed for continuous, streaming data applications, it could be quite hungry when it came to power usage. So much so that if Bluetooth is left on in a battery-powered device, battery life can suffer.

This led to the development of Bluetooth LE, or Low Energy. It has also been marketed as Bluetooth Smart, Bluetooth 4 or simply BLE. As its name suggests, the key difference between Bluetooth and Bluetooth Low Energy is the latter's lower (usually very much lower) power consumption. One reason is that BLE remains in "sleep mode" for a lot of the time and only wakes when it is required.

This also highlights another difference between Bluetooth and BLE: Bluetooth can exchange a lot of data at a close range. BLE, on the other hand, is intended for applications which are only required to exchange small amounts of data, periodically.

Connection times for BLE may be only a few milliseconds, where Bluetooth might remain on for around 100ms. The main reason for this is that BLE has much higher data rates – around 1Mb/s.

The development of BLE has spawned numerous devices with, for example, small button cell batteries. And in particular BLE finds many applications in the IoT.

Key features of Bluetooth Low Energy include:

- Industry-standard wireless protocol that allows for multi-vendor interoperability
- Ultra-low peak, average and idle mode power consumption that gives the ability to run for months on standard coin-cell batteries
- Standardised application development architecture that leads to low development and operational costs
- Allows for some of the tightest security in the industry with 128-bit AES data encryption

Bluetooth LE has really come into its own with the proliferation of the IoT along with its Android and Apple smart phone and tablet apps. Devices with Android V4.4 or iOS V7.0 and later is usually (but not always) compatible with BLE.

There's a ready market in consumer applications and devices. For example, you wake up and go for a run with a heart rate monitor that communicates with your smart watch, then listen to music through your shower head. You unlock your doors, set the temperature, turn on the lights and control your TV using the smartphone or tablet you already own. All these wirelessly connected devices are possible – today – with Bluetooth LE technology.

You should be aware, however, that having Bluetooth turned on on your phone could mean significantly more battery drain; we found that the phone required charging around twice as much as when Bluetooth was turned off.

Happy 40th Birthday, ALTRONICS

It may come as a surprise to many readers that Altronics will celebrate 40 years in business in December, this month! From a small start they have steadily grown and now have six stores and over 60 resellers spread throughout Australia and New Zealand.

By Leo Simpson

Jack O'Donnell, the owner and founder of Altronics, has actually been in business since January 1974 when he started what is now Ampac Technologies Pty Ltd, which still operates today, in Balcatta in Perth.

Ampac is the largest independent and privately owned supplier of fire detection and alarm systems in Australia. But back in 1976 Jack O'Donnell saw a great opportunity to become a reseller for Dick Smith Electronics in Perth.

So he started Altronics in December 1976 as a Dick Smith Electronics reseller and since there was no other similar business selling DSE parts in Perth, the venture went well.

Dick Smith Electronics soon recognised Jack's success, as he was going "gang-busters" (in fact, Altronics was far and away Dick Smith Electronics largest reseller at the time).

So much so that Ike Bain, the General Manager and the person responsible for opening new DSE stores, decided to open up a Perth store in 1979, competing directly against Jack.

Jack was appalled! But he did not take it lying down. Accordingly, he ceased operating as a DSE dealer in April 1979 and he decided to open up a new business, carrying its own range of electronic parts.

As part of that process, he sold Ampac in 1979 and started Altronics Distributors in January 1980.

His first store was a tiny operation in 151 York Street, Subiaco, Perth.

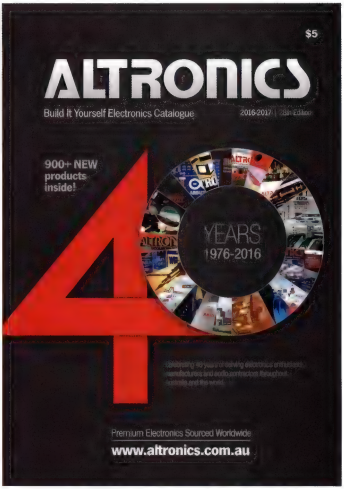
This was a very courageous move on Jack's part because Dick Smith Electronics was booming at the time and as evidence of that, during 1979 they had lots of advertising in *Electronics Australia* magazine.

For example, in the August 1979 issue, DSE had no less than eight pages of advertising.

Also not to be forgotten was that Tandy Electronics was rampant at the time – they had a 144-page catalog in the October 1979 issue of *EA*. So Jack O'Donnell could expect some pretty heavy competition as he started out.

But Jack's deliberate strategy was to import and distribute products which he had previously bought from DSE as a reseller. To top it off, he decided to also do kits for projects published

This wasn't even Altronics' first "warehouse" – it's the original Ampac Technologies "headquarters" in Murchison St. Ampac is still in business today but is now swamped by the success of Altronics.



Altronics first 32-page catalog, from 1980 and their latest 388-page monster included free with SILICON CHIP in March this year.

in the two magazines at the time, *Electronics Australia* and *Electronics Today International*.

Just incidentally, Ike Bain proclaimed on the opening of the Perth store that Altronics would be gone within 12 months. Well, Jack likes to state that Altronics is still going strong...

In fact, they've recently moved their Cannington store into much larger premises next door – which used to house Dick Smith Electronics!

One year after starting Altronics Distributors as a new business, Jack's first full page advert appeared in the January 1981 issue of *EA* and was billed as a "sensible alternative to Tandy and Dick Smith".

Not only that, by that time Altronics was supplying other parts retailers like Radio Despatch Service in Sydney and Ellistronics, in Melbourne. Altronics had an even bigger splash in the March 1981 issue of *EA*, with a 2-page spread and they featured in *EA* from that point on.

Then in March 1982 the first edition of the Altronics catalog, with 32 pages, appeared in *Electronics Australia*.

By that time Altronics had a store in Stirling Street, Perth and a warehouse in Subiaco. Most recently, the 28th edition of the catalog was a thumping 384 pages and was bundled with the March 2016 issue of SILICON CHIP.

Altronics now have six stores and over 60 resellers throughout Australia and New Zealand (many of whom

. . . to the current warehouse and distribution centre in Ledgar Rd, Balcatta. But even this is bursting at the seams – Altronics are currently drawing up plans for a HUGE new warehouse/distribution centre in Balcatta,

Altronics' own "Redback" range of professional PA Equipment has earned a huge following amongsts pro audio installers and users. This Matrix Mixer (Cat A4480A) is typical of the very high quality equipment made here in Australia by Altronics.

used to be Dick Smith Electronics resellers!).

But Altronics have not been content to just market an ever-increasing range of electronics parts and kits. As well, they have developed a strong manufacturing arm, producing a wide range of public address equipment under the Redback brand.

In fact, Jack and later Altronics, have been manufacturing PA equipment under the Redback brand since 1974 and this was built on Jack O'Donnell's wide experience in the industry.

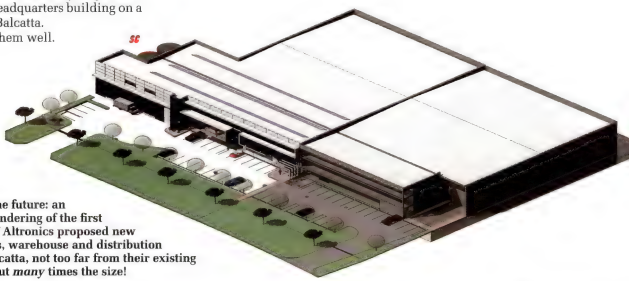
Altronics now have a very wide customer base and they are a major suppler to Ampac Technologies (funny, that).

Furthermore, all of the Redback products are designed in the Altronics headquarters in Perth and virtually all of the electronic equipment is manufactured there as well.

So what's next? Jack and his management team are planning for a very strong future and as evidence of that, they have plans for a very large warehouse and headquarters building on a new site in Balcatta.

We wish them well.

As well as their main distribution centre in Perth, Altronics maintain warehouses in Sydney, Melbourne and Brisbane to service the east coast, ensuring volume customers never have to wait for their orders.



And here's the future: an architect's rendering of the first two stages of Altronics proposed new headquarters, warehouse and distribution centre at Balcatta, not too far from their existing warehouse but *many* times the size!

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Build yourself a DIGITAL THEREMIN using Arduino

By BAO SMITH

SILICON CHIP has described quite a number of Theremins over the years but this is something new: an Arduino-based Theremin with hand sensing via an acoustic distance sensor.

THE THEREMIN is one of the first electronic musical instruments, and the first to be played without physical contact.

It was patented by the Russian inventor Lev Termen in 1928 and is played by waving your hands near two metal plates or antennas. The proximity of your hands is used to alter the instrument's pitch and volume and it has been used many times in movies and by pop bands.

Part of its appeal comes from its ethereal sound and you can see why if you take a look at a few videos of it being played. To find them, just do a Google search for "Theremin". For a list of previous Theremin projects described in SILICON CHIP, see the panel at the end of this article.

This Arduino version of a Theremin was devised by the technical staff at Jaycar Electronics and instead of using analog circuitry to sense hand proximity, it uses a standard Arduino shield, an ultrasonic sensor module, to sense your hand movement.

It only varies the pitch and is quite effective at that, but volume can only be varied by using the volume control on a small amplifier module.

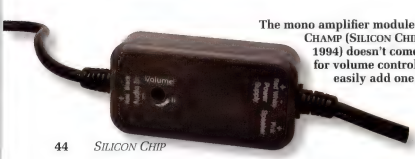
We have a separate article describing the circuitry of the HC-SR04 ultrasonic module elsewhere in this issue.

Jaycar sells a kit for this Arduino Theremin and it consists of a Arduino Uno (XC-4410; which is based on an ATmega328P microcontroller), an Arduino prototyping shield (XC-4482), an ultrasonic sensor module (XC-4422), an amplifier module (AA-0373) and a 40mm plastic cone loudspeaker (AS-3004). The kit is available for just $65.30, or less if you have one of Jaycar's "Nerd Perks" cards.

Putting this project together is quite simple but you will need a PC that can run the Arduino IDE, which can be found at **www.arduino.cc/en/Main/Software**

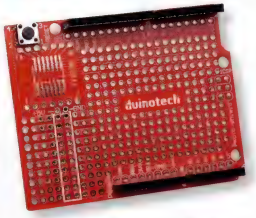
Jaycar has posted instructions to build this Theremin at: **www.jaycar.com.au/diy-ultrasonic-theremin**

We suggest you have a good look at those instructions but we have taken



The mono amplifier module based on the CHAMP (SILICON CHIP, February 1994) doesn't come with a knob for volume control, but you can easily add one yourself.

In this amplifier module, the leads were soldered and glued to the PCB, making removing them quite difficult.



The prototyping board provides headers to connect with the main Arduino board plus through-hole solder pads, along with a reset switch.

Step 1: the Speaker lead from the amplifier module needs to be soldered to the underside of the speaker. It doesn't matter which lead goes to which solder pad.

a slightly different approach here, which you may prefer.

Putting it together

The prototyping shield can be plugged on top of the Uno board first. Next, you connect the amplifier module to the speaker and then to the prototyping board. This module is actually a built-up version of our very popular CHAMP amplifier which was published in the February 1994 issue of SILICON CHIP. This version is on a slightly smaller PCB and housed in a neat plastic case.

Jaycar recommends removing the PCB from the amplifier module, extracting all leads from it and mounting it on the prototyping shield using wire soldered to the underside of the PCB.

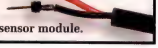
This would be advisable if you want to add an external volume control which can be easily manipulated while you are playing the instrument.

As supplied, the module comes with a tiny preset volume potentiometer on the PCB and that is a bit tricky to adjust. However, it's much easier to leave the amplifier in its case and just wire it up to the board. The reason we did this is to let us easily swap around components on the board, making adjustments easier, and allows us to reuse each part for different projects.

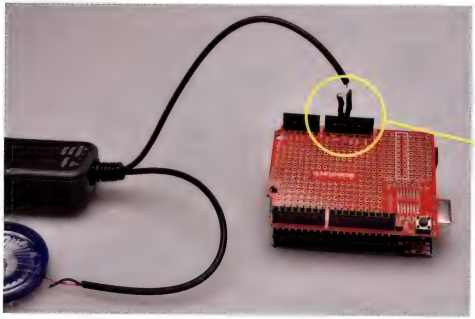
Step 1: solder the speaker positive (pink) and negative (black) leads from the amplifier module to the speaker's terminals (either way around).

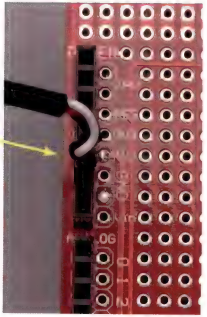
Step 2: make the connections to

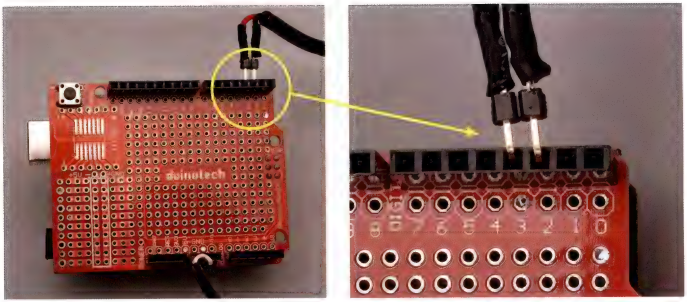
You may want to solder a two-pin (or two one-pin) header(s) to the input and power leads from the amplifier. Keep in mind for the amplifier Audio In, right-angle header(s) need to be used if connecting to the female header. This is needed for clearance from the sensor module.



Step 2: the Power Supply positive lead (red) from the amplifier goes to the 5V connection on the prototyping board. The negative lead (white) can then go to either of the two GND connections nearby. We've used a two-pin male header and added heatshrink tubing over the solder joints to provide greater strength.







Step 3: the amplifier Audio In positive lead (red) needs to be plugged into DIGITAL pin 3. The negative lead (black) is not needed and so can go to any unused pin. Here we have the negative lead plugged into pin 2 directly next to the positive lead, but you can choose what works most comfortably for yourself.

power the amplifier module. We soldered the red and black supply leads to a 2-pin male header that can then be plugged directly into the 5V and GND pins on the prototyping shield, which are indicated on the silkscreen printing.

Step 3: solder the red and black input leads of the amplifier module to a 2-pin right-angle header and then plug it into pin 2 (for the black wire) and pin 3 (for the red wire), on the opposite side of the prototyping shield from the power supply connection.

Step 4: make sure the proto shield is correctly plugged into the Uno board.

Step 5: straighten the pins on the ultrasonic sensor and plug it into the prototyping board header next to the amplifier audio input leads. Its four pins are labelled V_{CC}, Trig, Echo & GND. These are plugged into the DIGITAL shield pins with V_{CC} to pin 8, Trig to pin 9, Echo to pin 10 and GND to pin 11. These are default pin locations set by the software but you could modify the software to change them, as explained later in this article.

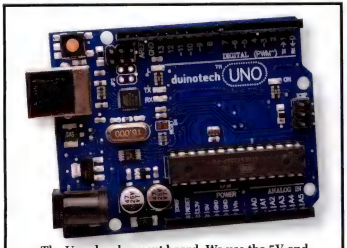
All the above connections are listed in the table entitled "Lead Connections" later in this article, so refer to that if you're unsure.

With all parts connected, the next step is loading the software on the ATmega328P chip via the Arduino IDE. The original software can be found at: www.jaycar.com.au/diy-ultrasonic-theremin#sketchfiles

There will be two files, **Ultrasonic_Theremin.ino** and **sample.c** and these should be downloaded to a folder on your PC named "Ultrasonic_Theremin". The Arduino must be connected to your computer using a USB Type-A to Type-B cable (as commonly used for printers) so that the software can be loaded onto it.

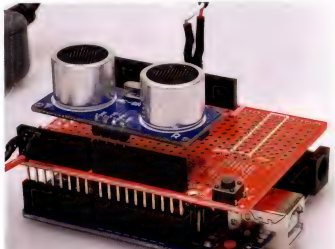
Steps 6 & 7: once the Arduino IDE

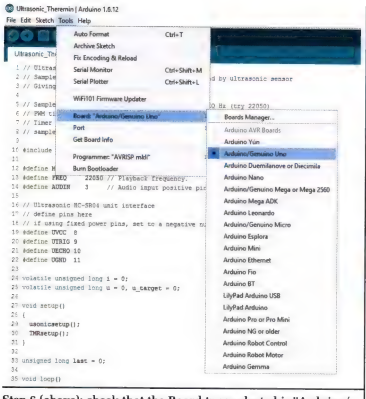
Step 4: if you haven't already done it, now is the time to plug the proto shield into the Uno board. The orientation is simple as both reset switches should be in the same location.



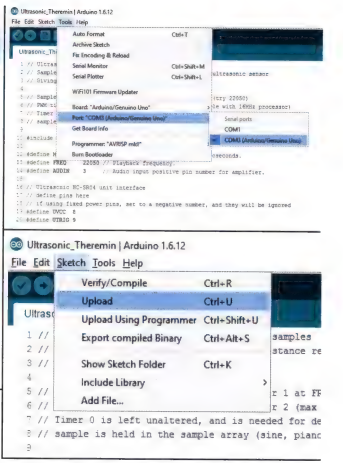
The Uno development board. We use the 5V and GND pins on the POWER header, one PWM~ and four DIGITAL pins for the Theremin.

Step 5: the ultrasonic sensor needs to have its pins straightened and then it can be plugged into the female header with V_{CC} on DIGITAL pin 8 and Trig on pin 9.





Step 6 (above): check that the Board type selected is "Arduino/ Genuino Uno" in the Arduino IDE, before uploading the software to the board.



Step 8: using the Arduino IDE, upload the software onto the board. Assuming there have been no changes, it should compile and run correctly.

Step 7 (upper right): While the Uno is plugged into the computer, check that Port is correctly set to the one that the device is connected to. In this case, ours is on serial port COM3.

has been installed, open **Ultrasonic_ Theremin.ino** in it and on the menu bar, go to **Tools** and check that the board is set to "Arduino/Genuine Uno" and that **Port** is "COMX (Arduino/Genuine Uno)", where X is whatever port number it has been assigned to on your PC. If your board does not show up in this list, you may need to manually install the drivers for it. Instructions on how to do this can be found at: **www.arduino.cc/en/Guide/ArduinoUno**

The Arduino uses Virtual COM Port (VCP) drivers to emulate a COM port over a serial connection. If you're interested, it will be explained in greater detail in the next Low-Cost Asian Electronic Modules article on the CP2102 USB-UART bridge in next month's SILICON CHIP magazine.

Step 8: if everything is in working order, on the menu bar go to **Sketch → Upload**. This will compile and upload the software onto the Arduino. The device can then be tested by holding your hand over the ultrasonic sensor. It should produce a sound with a pitch which increases as your hand gets closer to the sensor and conversely, lowers as your hand moves away from the sensor.

If you don't get any sound, check that the amplifier is wired to the correct pins on the prototyping shield and that the compilation and uploading proceeded with no errors, which

The HC-SR04 ultrasonic sensor module, described in greater detail in the article on page 82.

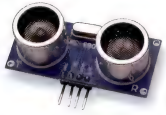


Table 1: Lead Connections

Component	Lead	To Header/Part	To Pin
Amp Power Supply (4-12V)	+ (red)	POWER	5V
	- (white)	POWER	GND
Speaker	± (pink/white)	Mono speaker	
Amplifier Audio Input	+ (red)	DIGITAL	3
	- (black)		any unused
Ultrasonic Sensor	V_{CC}	DIGITAL	8
	Trig		9
	Echo		10
	GND		11

would be displayed at the bottom of the Arduino IDE window.

Besides communication issues, the most likely problem would be if the two provided files are not in the same directory.

Once the software has been uploaded to the device, rather than plugging it into your PC, it can be powered via a 7-12V DC power supply or battery, via the DC barrel socket located next to the USB connector.

Making some improvements

Once you have it running, you will probably find that the Theremin sound is not particularly good and not like the Theremins that you will have seen on videos on YouTube.

With that in mind, we modified the software to give a more realistic Theremin sound, more like that which could be produced by one of the previous SILICON CHIP Theremins listed elsewhere in this article.

The important change is the addition of a sinewave look-up table which is substantially smaller (256 bytes compared to 16 kilobytes) than playing back a larger digital sample at a varying rate to control the pitch. This is especially important when considering that memory on the micro is quite sparse, at 31.5KB of usable flash and 2KB of SRAM.

The SILICON CHIP version of the software is available for free on our website (**www.siliconchip.com.au**). Download the two files which are labelled **SC_Ultrasonic_Theremin.ino** and **SC_sample.c**. They should unzip into a suitably named directory ("SC_Ultrasonic_Theremin"). You then upload them to the Uno using the same procedure as described above. We hope you find the resultant sound more satisfying.

One of the advantages of using an Arduino to build this Theremin is that you can easily modify the software if you want to. For example, you could change the linearity of the pitch control or change the waveform. If you do want to modify the software, it would be a good idea to familiarise yourself with a programming language like C or Java. However, even inexperienced readers may have some luck making simple changes.

For example, at the top of the .ino file, some macros are defined which allow you to easily change certain properties of the Theremin:

- MAX_DIST sets the maximum distance for the range sensor, with a value of 5700 approximately equal to 1m. The sensor has an effective range of 2-400cm, although in practice it will barely work beyond 3m, which gives MAX_DIST at most being 300cm ÷ 0.0175cm/µs ≈ 17000 (µs). Note that 0.0175cm/µs is half the speed of sound at 25°C and 100kPa.
- FREQ sets the default playback frequency for the sample. Generally, anything within 22050 ± 5000 (ie, half the sampling rate of a CD) sounds best, but depending on the sample used, your results may vary.
- UVCC, UTRIG, etc define the pin location for the ultrasonic sensor. These can be changed if you want to move the sensor to a different location on the board.

Also, there are four different samples you can use with the Theremin (in sample.c): sine, piano, theremin and sine256. The first three can be easily selected to by changing the name referenced on line 67 of the .ino file, ie:

```
OCR2B = pgm_read_byte
(&theremin[i >> 18]);
```

Here, you can change "theremin" to "piano" or "sine". If you want to use sine256 instead you need to comment out this line (by prefixing it with two slashes, ie, "//"), and un-comment the one above.

Without difficult changes you cannot use the other PWM-enabled pins for the amplifier audio in. Since any DIGITAL pin that the amplifier audio input is on needs to be matched with corresponding OCR register settings, if the pin location is changed the OCR referenced in the code needs to be changed too. For example, by default we use the OCR2 (pins 3 and 11) register which is an 8-bit register, while the other 8-bit register OCR0 (on pins 5 & 6) could also be used. However, OCR1 (pins 9 & 10) is a 16-bit register making working with them quite different.

If you know what you're doing you can alter this, otherwise it's best not to. You can find the pin mapping for the chip here: **https://www.arduino.cc/en/Hacking/PinMapping168** and the ATmega328P documentation here: **http://www.siliconchip.com.au/l/aaai**

Where to get it

All the components for the kit can be purchased from Jaycar as a kit for $65.30, or $52 if you have a Nerd Perks card. It is available from their retail stores and their website (**www.jaycar.com.au**).

The speaker and amplifier module can easily be substituted to obtain more power and better bass and that should make it considerably more satisfying to play.

Finally, for a detailed Arduino installation guide, see: **www.arduino.cc/en/Guide/HomePage**

Next month, we hope to publish details on how to add a second ultrasonic module to control the volume of the Theremin. This will be accompanied with changes to the software. SC

Parts List

Ultrasonic Theremin Project Kit

1 Uno Main Board (Jaycar XC4410)
1 Arduino Prototyping Shield (Jaycar XC4482)
1 Ultrasonic Sensor Module (Jaycar XC4442)
1 Mono Amplifier Module (Jaycar AA0373 or equivalent)
1 8Ω 1/4W 40MM Speaker (Jaycar AS3004 or equivalent)

Additional items

1 USB Type-B to Type-A male-male connector (e.g, printer cable)
1 7-12V DC plugpack (if you want to run it without USB)
1 2-pin male header
1 2-pin male right-angle header

SILICON CHIP Theremin Projects

1. Opto-Theremin*, September & October 2014
2. The Theremin Mk.2 with improved voicing, March 2009
3. Mini-Theremin, July & August 2006
4. MIDI Theremin, April & May 2005
5. The Theremin, August 2005

* Note: PCBs and key parts for the Opto-Theremin project are available from the SILICON CHIP shop – see our website for more details (**www.siliconchip.com.au/Shop**).

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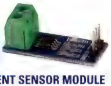

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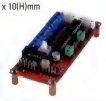

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Finished project

DIY

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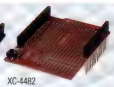
XC-4410



XC-4482

RR-0554

ZD-0150

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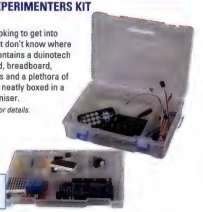
For those looking to get into Arduino® but don't know where to start. It contains a duinotech MEGA board, breadboard, jumper wires and a plethora of peripherals, neatly boxed in a plastic organiser.

See website for details.



$109

$3.25 ea

NERD PERKS 2x POINTS

LIGHT DEPENDENT RESISTOR (LDR)

Cadmium Sulphide (CdS) light dependent resistor cells, suitable for all your light-sensitive projects.

2.8K OHM TO 8.4K OHM RD-3485

48K OHM TO 140K OHM RD-3480

$11.50

NERD PERKS 2x POINTS

POLYMORPH PELLETS NP-4260

Softens to be formed into any shape at around 62 - 65° C. It can be drilled, sanded, ground, machined or heated and reformed again and again. 100g bag of 3mm pellets.

$14.95

NERD PERKS 2x POINTS

JUMPER LEAD ASSORTMENT KIT - 90 PIECES WC-6029

Used in Arduino® projects, school experiments and other hobbyist activities. 220mm in length and 2mm in width.

$16.95

NERD PERKS 2x POINTS

RESISTOR PACK 300-PIECES

RR-0680

This assorted pack contains 5 of virtually each value from 10Ω to 1MΩ.

- 0.5W 1% mini size metal film

See website for full contents.

TOOLS FOR YOUR POWER PROJECTS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

2 FOR $50 OVER 15% OFF

NOW $54.95 SAVE $5

1. 210 ROTARY TOOL KIT WITH FLEXIBLE SHAFT TD-2459

Consists of a powerful mains powered 32,000 RPM rotary tool that can be used with numerous attachments in the usual way.

- Suitable for modelmaking, automotive, workshop, art, jewellery or sculpture.

2. MAGNIFYING LAMP WITH THIRD HAND TH-1989

- LED illuminated 3x magnifying glass, soldering iron stand, alligator clips, solder spool holder, cleaning sponge & ball
- 4 x AA batteries required
- 190x170mm base size

3. NON-CONTACT THERMOMETER QM-7215 **WAS $59.95**

Safely measure temperature in hot, hazardous, or hard to reach places. 8:1 distance to spot ratio. Laser pointing targeting . Backlit LCD.

- Temp range -30°C to +260°C
- 8:1 Distance to spot ratio

4. VARIABLE LABORATORY AUTOTRANSFOMER (VARIAC) MP-3080 **WAS $239**

- Heavy-duty steel housing
- AC input to mains powered appliances
- Rated power handling: 500 VA (fused)
- Output Voltage: 0–260 VAC @ 50Hz
- 165(D) x 120(W) x 160(H)mm

5. GAS SOLDERING IRON TOOL KIT TS-1328

Ideal for urgent soldering needs. Includes a quality Portasol® Super Pro iron with various tips, quality storage case and cleaning sponge/tray.

6. 33 DRAWER PARTS CABINET HB-6330 **$29.95 EA.**

- 32 small drawers 125(D) x 85(W)mm
- One full width pull out drawer
- Free standing or wall mountable
- 414(H) x 304(W) x 135(D)mm

NOW $219 SAVE $20

$44.95

$159

$54.95

BENCHTOP POWER SUPPLIES

Our range of highly efficient and reliable benchtop power supplies are specially selected to suit your unique testing and servicing applications. They use proven technology and are designed to give long service life in workshop situations. Features include low noise, low ripple and protection against overload and short circuit. Available in fixed or variable voltage and current models, they make the most cost effective solution for your laboratory use, electronic and communications equipment maintenance.

	MP-3097	MP-3840	MP-3090	MP-3087
Features	Fused input, fixed output voltage, also available in 5A & 20A models	Digital control & a large easy to read LED display. Over-current & short circuit protection are built-in	High powered, variable or fixed output voltage	Automatic constant voltage/current, dual output with flexible connection
Output Voltage	13.8VDC	0-30VDC	3 to 15VDC or 13.8VDC fixed	0 to 32VDC (x 2)
Output Current	10A	0-5A	40A	0 to 3A (x 2)
Ripple Voltage	120mV	<1.0mVRMS	10mVRMS	<1mVRMS
(W) x(D) x (H)	153 x 233 x 100mm	110 x 156 x 260mm	300 x 220 x 110mm	260 x 400 x 185mm

$149 MP-3097

$179 MP-3840

$379 MP-3090

$399 MP-3087

NOW $19.95 SAVE $5

INSULATED SIDE CUTTERS

TH-1985 **WAS $24.95**

STRONG, TOUGH & RELIABLE For serious tradesmen who need a quality tool. It will cut hard (piano wire) wire up to 1.6mm. Designed for dedicated wire cutting. Comfortable double inset handles. GS approved. 1KV rated.

- 160mm/6" long

NOW $24.95 SAVE $5

HEAVY DUTY CRIMPER / STRIPPER / CUTTER

TH-1827 **WAS $29.95**

Can strip all types of cable from AWG 10-24 gauge (0.13 -6.0mm).

- Crimps insulated & non-insulated terminals (1.5 - 6mm)
- Crimps auto ignition terminals (7-8mm)

FROM $25¢/m *Sold per metre or 100m roll.

GENERAL PURPOSE POWER CABLES

FLEXIBLE LIGHT DUTY Suitable for general purpose wiring. 13x 0.12mm. PVC insulation. 0.6A rated current. Multiple colours available. WH-3010 - WH-3017 **25¢/m or $15/roll**

HEAVY DUTY Suitable for 250V wiring. 24 x 0.2mm. PVC insulation. 7.5A rated current. WH-3040 **55¢/m or $42/roll**

EXTRA HEAVY DUTY Suitable for 250V wiring. 32 x 0.2 mm. PVC insulation. 10A rated current WH-3052 **80¢/m or $72 roll**

FROM $1.25/m *Sold per metre or 100m roll.

AC MAINS CABLES

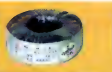
TWO CORE MAINS FLEX

7.5A WB-1560 **$1.25/m or $99/roll**

THREE CORE MAINS FLEX

10A WB-1562 **$2.85/m or $229/roll**

NERD PERKS
FROM
$19.95
SAVE $5



20VA TOROIDAL TRANSFORMER

High efficiency, small size, & low electrically induced noise. Single bolt mounting.

- Outer/Inner 74mm / 21 x 30mm.

12V+12V 0.833A SERIES 1.66A PARALLEL
MT-2084 **RRP $24.95 NERD PERKS $19.95**
SAVE $5

15V+15V 0.666A SERIES 1.333A PARALLEL
MT-2086 **RRP $24.95 NERD PERKS $19.95**
SAVE $5

9V+9V 1.11A SERIES 2.22A PARALLEL
MT-2092 **RRP $29.95 NERD PERKS $24.95**
SAVE $5

NERD PERKS
SPECIAL
$39.95
SAVE $10

50VA 240VAC TO 115VAC STEPDOWN TRANSFORMER

MF-1091 **RRP $49.95**

Overheat protection via thermal fuse. Two pin US socket on unit for 110V appliance and cord plug for 240V power.

- Not dielectrically isolated

NERD PERKS
SPECIAL
$21.95
SAVE $6

24V EI CORE TRANSFORMER

MM-2012 **RRP $27.95**

Type 2158 single winding transformer with 20mm fly leads on primary and secondary connections.

- 24V, 72VA, 3A rated

NERD PERKS
FROM
$99
SAVE UP TO $50

ISOLATED STEPDOWN TRANSFORMERS

Fully-enclosed with fold up carry handles, approved 3-wire power cord & US style 2 pin 110 - 115V socket. Electrically isolated between primary and secondary.

120W 240V - 115V MF-1090
RRP $119 NERD PERKS $99 SAVE $20
250W 240V - 115V MF-1092
RRP $169 NERD PERKS $149 SAVE $20
500W 240V - 115V MF-1094
RRP $289 NERD PERKS $249 SAVE $40
1000W 240V - 115V MF-1086
RRP $419 NERD PERKS $369 SAVE $50

POWER SUPPLIES

MAINS POWER ADAPTORS

Regulated output voltage. Suitable for thousands of different applications.

5VDC 3.0A MP-3480
6VDC 2.2A MP-3482
9VDC 1.7A MP-3484
12VDC 1.5A MP-3486

$24.95

12VDC 7.5A SWITCHMODE POWER SUPPLY MP-3575

Power 12V equipment such as car coolers, camping fridges, etc, from a mains AC power source. Supplied with a 1.5m output lead with cigarette socket output.

- 57(L) x 90(W) x 57(H)mm

$44.95

DESKTOP AC ADAPTORS

Low profile. IEC lead required - use PS-4106.

12VDC 5A MP-3242 **$59.95**
19VDC 3.42A MP-3246 **$59.95**
24VDC 2.7A MP-3248 **$59.95**
12VDC (5 PLUGS) 5A MP-3243 **$64.95**
3PIN MAINS PLUG TO IEC C13 FEMALE PS-4106 **$8.95**

FROM
$59.95

POWER ESSENTIALS

FROM
$4.95
NERD PERKS
2x POINTS

"JOW" CABLE CLAMP CONNECTORS

These easy-to-use connectors eliminate the need to strip, twist and crimp connect wires. Handles up to 600V.

"I" TYPE FOR END TO END CONNECTIONS:
3A 6 PACK PT-4640 **$5.95**
10A 4 PACK PT-4641 **$4.95**
"T" TYPE FOR PARALLEL CONNECTIONS:
3A 6 PACK PT-4650 **$6.95**
10A 4 PACK PT-4651 **$5.95**

$9.95
NERD PERKS
2x POINTS

IEC EMI POWER LINE FILTER - 6 AMP MS-4003

Designed to reduce line - to - ground (common mode) interference. Accepts standard IEC power plug and are panel mounted.

- Rated for mains voltages of 115 to 250V, 50, 60Hz
- Compliant with UL, CSA, VDE

FROM
$8.95
NERD PERKS
2x POINTS

MAINS POWER LEADS

IEC FEMALE TO 240V 1.8M
PS-4106 **$8.95**
IEC FEMALE TO IEC MALE 1.8M PS-4108 **$8.95**
IEC MALE TO 3 PIN FEMALE 150MM
PS-4100 **$9.95**
See website for full range.

12V TO 5V DC CONVERTER WIRING KIT MP-3675

Get rid of unsightly power cables (GPS, Dash Cam or mobile devices) that float around the car dash.

- Micro USB Plug (Mini USB adaptor included)
- 2.5A continuous current
- Cable length 1.3m

$19.95

25 WATT SWITCHMODE POWER SUPPLIES

Highly efficient and reliable power supplies that feature broad input voltage tolerances.

- Short circuit, overload & overvoltage protected
- Soft-start / Low Ripple DC
- 99 (L) x 97 (W) x 35 (H)mm, 370g

12V 2.1A MP-3160
24V 1.1A MP-3162

$44.95
2 YEAR WARRANTY

150 WATT SWITCHMODE POWER SUPPLIES

Includes automatic input voltage detection.

12V MP-3185
15V MP-3187
24V MP-3189
DIN RAIL BRACKET MP-3152 **$6.95**

$94.95
2 YEAR WARRANTY

WIN A SOLAR MOBILE RECHARGE POWER BANK

SIMPLY SUBMIT A PHOTO OF THE JAYCAR TOOL YOU CAN'T LIVE WITHOUT AND YOU COULD WIN.

WORTH $119 MB-3720

win.jaycar.com/workbench

Competition closes 23rd Dec. See website for the T&Cs.

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF

ALL GENERAL PURPOSE POWER & AC MAINS CABLES*

*(*Applies only to cables listed on page 4)*

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING: www.jaycar.com.au/nerdperks

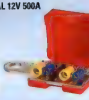
BATTERY MANAGEMENT

FROM $17.95

BATTERY ISOLATION SWITCHES

High current rated battery isolation switches for high power applications. They feature high quality construction with huge bolt down terminals for electrical connection.

HIGH QUALITY 12V 120A
SF-2245 **$17.95**
PROFESSIONAL 12V 500A
SF-2247 **$59.95**



$9.95

MULTI-CONNECT BATTERY TERMINAL - RED HM-3089

Can be used to terminate up to 4 devices.

- Red colour for positive connections
- Does not need screws
- Spade terminals included
- 75(L) x 40(W) x 20(H)mm

FROM $69.95

140A DUAL BATTERY ISOLATOR KIT MB-3686

Allows two batteries to be charged from your engine alternator at the same time.Suitable for 12VDC Marine, 4WD, caravan and solar applications.

- Emergency override feature
- LED status indicator

VSR WITH WIRING KIT MB-3686 **$159**
VSR WITHOUT WIRING KIT MB-3685 **$69.95**

$49.95

250A REMOTE BATTERY JUMPER TERMINALS HM-3075

This remote battery jumper terminal provides convenient access to the vehicle battery for charging or jump starting.

- Protective red & black rubber covers
- 50(W) x 130(L) x 20(H)mm

$44.95

BATTERY DISCHARGE PROTECTOR AA-0262

Protects your vehicle battery by switching off appliances before the battery voltage drops to an unrecoverable level. When voltage is established via recharging, it switches appliances on automatically.

- Operating voltage: 12VDC
- Max. switching current: 20A
- Interrupting voltage: 10.4 - 13.3VDC
- 87(L) x 60(W) x 32(H)mm

FROM $39.95

12VDC UNIVERSAL RELAY WIRING KITS

Universal relay wiring kits for fitting various 12V devices to your car, eg LED driving lights.

12VDC 7A - SINGLE SY-4075 **$39.95**
12VDC 13.5A - DUAL SY-4180 **$59.95**
12VDC 22.5A - DUAL SY-4182 **$79.95**

$89.95

DIGITAL DC POWER METERS

An ideal addition to any low voltage DC system this digital power meter features real time display of the voltage, current draw, and power consumption.

0-20A With internal shunt. MS-6170
0-200A For 50MV external shunt. MS-6172
ALSO AVAILABLE:
USB DATA ADAPTOR MS-6174 **$99.95**

$22.95

PANEL/SURFACE MOUNT LED VOLTMETER QP-5582

Monitors your battery voltage. Simply wire to a positive and negative DC power source of 5-30VDC.

TECH TIP

BATTERY MAINTENANCE

Periodic visual inspection of most batteries is recommended. If the battery is stored for over six months, it is recommended to charge and discharge the battery several times to recover the battery capacity, failure to do so may result in a loss of capacity and shorter battery life.

See in-store for comprehensive range of battery chargers.

LEAD ACID BATTERY CONDITIONER NA-1420

Removes or reduces sulphation which kills batteries. One bottle will do up to a N70Z size battery (4WD, boat, truck, etc.)

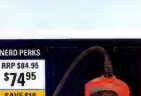
$10.95 NERD PERKS 2x POINTS

12VDC LEAD ACID BATTERY TESTER QP-2261

Quickly, easily, and accurately measures the cold cranking amps capability of the vehicle starting battery.

- Voltage Measure Range: 6-30VDC
- 125(L) x 70(W) x 25(H)mm

NERD PERKS
RRP $84.95
$74.95
SAVE $10



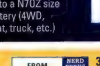
$7.95 NERD PERKS 2x POINTS

1.2V 1800MAH NI-CD SUB C RECHARGEABLE BATTERY

SB-2468

- Standard charge 180mA, 14-16Hrs
- Quick charge 600mA, 4-5Hrs

ALSO AVAILABLE:
1.2V NI-MH HIGH DISCHARGE 3300MAH SUB C RECHARGEABLE BATTERY SB-1611 **$8.95**



FROM $9.95 NERD PERKS 2x POINTS

3.7V LI-ION RECHARGEABLE BATTERIES

Choose between nipple or solder tabs to make into battery packs for replacement or new projects.

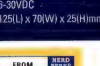
SB-2300

NIPPLE CONNECTION:

14500 800MAH	SB-2300 **$9.95**
18650 2600MAH	SB-2308 **$19.95**
26650 3400MAH	SB-2315 **$24.95**

SOLDER CONNECTION:

14500 800MAH	SB-2301 **$10.95**
18650 2600MAH	SB-2313 **$21.95**
26650 3400MAH	SB-2319 **$25.95**



FROM $9.95 NERD PERKS 2x POINTS

3.2V LIFEPO4 RECHARGEABLE BATTERIES

Lithium iron phosphate (LiFePO4) is a more chemically stable type of lithium rechargeable cell that is becoming increasingly popular, due to increased safety and longer cycle life over traditional Li-ion cells.

SB-2317

14500 600MAH SB-2305 **$8.95**
18650 1600MAH SB-2307 **$17.95**
26650 3000MAH SB-2317 **$24.95**

NOW $79.95
SAVE $10

UNIVERSAL PROGRAMMABLE BALANCED BATTERY CHARGER

MB-3632 **WAS $89.95**

Charges Li-ion, Li-Po, NI-Cd, Ni-MH and lead acid batteries. Li-Po batteries are balance-charged so there's no risk of damage or explosion from incorrect charging. Powered by mains plug pack or a 12V battery.

- LCD display
- 132(L) x 82(W) x 28(H)mm.

CONVERTERS & INVERTERS

DC TO DC STEP DOWN VOLTAGE CONVERTER MODULE AA-0236

Power your devices where a different power source is present.

- 6-28V DC Input voltage
- 3-15V DC Output voltage
- 1.5A
- 60(L) x 45(W) x 20(D)mm

Other models available. See website for more details.

$24.95

24V -12V 10A DC-DC CONVERTER WITH CIG IN/OUT MP-3352

DC to DC converts are useful for running 12V devices from a 24V supply in vehicles.

$89.95

24VDC TO 230VAC ELECTRICALLY ISOLATED INVERTER

High quality and reliable modified or pure sine wave inverters with USB port and offer standard protection features.

- 24VDC input, 230VAC output

MODIFIED SINEWAVE:
400W MI-5107 **$89.95**
2000W MI-5116 **$569**

PURE SINEWAVE:
360W MI-5703 **$339**
2000W MI-5712 **$1529**

FROM $89.95

HARNESS THE POWER OF THE SUN

SELECT YOUR SOLAR PANEL AND MOUNTING HARDWARE

SEMI FLEXIBLE SOLAR PANELS

12VDC. Ideal for mounting to curved or other irregular surfaces such as an RV roof or boat.

15W ZM-9149 **$79.95**
30W ZM-9151 **$139**
80W ZM-9153 **$329**

FROM **$79.95**

FIXED SOLAR PANELS

12VDC, monocrystalline solar panels. 25 year limited warranty on power output. Includes waterproof junction box.

80W ZM-9097 **$219**
120W ZM-9085 **$319**
145W ZM-9087 **$369**

FROM **$219**

SOLAR PANEL FIXED ALUMINIUM SIDE BRACKET HS-8780

Your ideal solution for mounting solar panels in caravan, motor home, shed or marine applications. Provides secure and easy mounting, and space the panel for airflow.

See website for full range.

$7.95 ea

FROM **$24.95** HS-8860

SOLAR PANEL MOUNTING BRACKETS

Attach your solar panel to your mounting surface.

CORNER MOUNTING BRACKETS HS-8860 **$39.95 SET OF 4**

FIXED ABS SIDE BRACKETS WHITE HS-8862 **$24.95 PAIR**

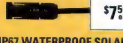
CONNECT YOUR SOLAR PANEL

FROM **$4.95** ea — NERD PERKS 2x POINTS

SOLAR SYSTEM CABLE

Very tough cable suited for the rigours of outdoor use in solar panel installations. Dust, age and UV resistant, tinned copper conductors to minimise corrosion.

4MM² 58A RATED WH-3121 **$4.95/M or $435/100m roll**
6MM² 76A RATED WH-3122 **$7.95/M or $699/100m roll**



$7.50 ea — NERD PERKS 2x POINTS

IP67 WATERPROOF SOLAR POWER PV CONNECTORS

- 1000VDC rated voltage
- 30A at 70°C, 25A at 85°C rated current

4MM FEMALE INLINE PS-5100
4MM MALE INLINE PP-5102
6MM FEMALE PANEL MOUNT PS-5104
6MM MALE PANEL MOUNT PP-5106

NERD PERKS **BOTH FOR $59.95** SAVE $19.95

HEAVY DUTY CRIMP TOOL WITH QUICK INTERCHANGEABLE DIES

TH-2000 **RRP $49.95**

Uses quick interchangeable dies, no screwdriver needed. Features ratchet mechanism for maximum power and quick release. Dies sold separately.

PV CONNECTOR Die to suit TH-2000. TH-2010 **$29.95**

$19.95 ea — NERD PERKS 2x POINTS

SOLAR PANEL 'Y' LEADS

Used for connecting the output of two solar panels in parallel or connecting multiple panels in an array. Waterproof and UV resistant.

2 SOCKET TO 1 PLUG PS-5110
2 PLUGS TO 1 SOCKET PS-5112

FROM **$9.95** ea — NERD PERKS 2x POINTS

POWER DISTRIBUTION POSTS WITH BRIDGE PLATE

Heavy duty stainless steel posts mounted on a moulded plastic base.

SINGLE M10 SZ-2090 **$9.95**
TWIN M8 SZ-2092 **$11.95**
TWIN M6 POWER SZ-2094 **$11.95**

FROM **$9.95** ea — NERD PERKS 2x POINTS

ULTRA HIGH CURRENT FUSES

Designed for high current protection. Commonly used for battery and alternator connections and other heavy gauge cables requiring ultra high current protection.

BOLT-DOWN FUSE 125A SF-1982 **$9.95**
BOLT-DOWN FUSE 250A SF-1984 **$9.95**
HIGH CURRENT FUSE HOLDER SF-1980 **$24.95**

$4.95 ea — NERD PERKS 2x POINTS

240VAC HIGH CURRENT CIRCUIT BREAKERS

DIN rail mounted circuit breakers suitable for solar applications. Electrical safety authority approved.

10A SINGLE POLE SF-4150
16A SINGLE POLE SF-4151
20A SINGLE POLE SF-4152
32A SINGLE POLE SF-4153

$19.95 ea — NERD PERKS 2x POINTS

SOLAR PANEL PV PLUG AND SOCKET TO 50A ANDERSON PLUG - 300MM PS-5122

4mm² conductor 30 amp capacity, twin sheath high quality cable. Comes with grommets on each side for straightforward and neater installations.

STORE YOUR ENERGY

SB-1695

SB-1698

FROM **$149**

12VDC SLA DEEP-CYCLE GEL BATTERY

Leakproof and completely sealed, ideal for solar power, 4WD, camping, etc

26AH SB-1698 **$149**
38AH SB-1699 **$239**
100AH SB-1695 **$369**

$839

12V 150AH SLEEK AGM DEEP CYCLE BATTERY SB-1822

Superior high rate discharge performance and higher cycle service life. Perfect for applications including remote solar systems, caravan and RV, motorhome, and marine.

- 123(W) x 556(D) x 296(H)mm

See website for full specifications.

MAXIMISE THE CHARGE

$29.95

12V 5A BATTERY SOLAR CHARGING CONTROLLERS

AA-0348

Suits 12V panels up to 60W.

- 72(W) x 50(D) x 43(H)mm

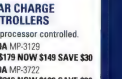
$79.95

20A SUPER SOLAR PANEL CONTROLLERS

MP-3126

It installs easily and features automatic operation,

- 66(L) x 51(W) x 34(H)mm



FROM **$149** SAVE $30 MP-3129

SOLAR CHARGE CONTROLLERS

Microprocessor controlled.

12V 20A MP-3129 **WAS $179 NOW $149 SAVE $30**
12V 30A MP-3722 **WAS $219 NOW $189 SAVE $30**

TECH TIP

SOLAR CHARGE CONTROLLERS

Directly connecting a solar panel array to a battery can be catastrophic as solar panels can output a wide voltage range. A solar charge controller between the panel and the battery ensures the battery receives the correct output voltage and current from the panel to minimise the risk of the battery being overcharged or discharging back into the panels.

CLEARANCE

Selected lines. Not available online. Quantities may be limited.

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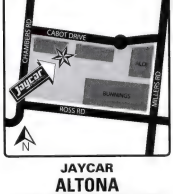

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from 24 November- 24 December, 2016.

PRODUCT SHOWCASE

Industrial-Scale 3D Printing of High-Strength Carbon Fibre Parts

Markforged, represented in Australia by Emona Instruments, has announced the industry's most powerful fibre-composite 3D printer, the Mark X. The Mark X's high strength carbon fibre 3D printed parts will be in demand for both prototyping and manufacturing scale parts printing for mining, manufacturing, renewables, medical prosthetics and electronics/telecommunications applications.

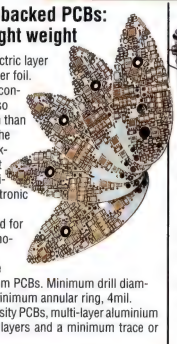
In addition to the large print volume of 330mm x 250mm x 200mm (X, Y, Z), it has in-process laser inspection as well as a fine (50 micron) surface finish to make this one of the most powerful, precise, and unique 3D printers on the market today.

"We have taken a different path from most of the 3D printing industry with innovation that will create a new bottom line benefit for many manufacturers" says Greg Mark, CEO and founder.

"We already had success with the breakthrough strength and light weight of continuous carbon fibre in our Mark Two printer – now we have added in-process inspection for exact dimensional accuracy, high resolution beautiful surface finish, and scale to open entirely new segments of the industry to efficiencies of what printing can accomplish."

Contact:
Emona Instruments Pty Ltd
PO Box 15, Camperdown NSW 1450
Tel: (02) 9519 3933 Fax: (02) 9550 1378
Web: www.emona.com.au

PCBCart's aluminium-backed PCBs: heat dissipation and light weight



Aluminium PCBs contain a dielectric layer between aluminium base and copper foil.

The dielectric layer is thermally conductive but electrically insulating, so that it offers better heat dissipation than conventional PCBs. Furthermore, the dielectric layer has such a low thickness that aluminium PCBs are light in weight, compatible with the miniature requirements of modern electronic products.

Aluminium PCBs are largely used for LEDs, power equipment and automotive systems.

For better heat dissipation, there are FR4 and through-hole aluminium PCBs. Minimum drill diameter can be as small as 8mil and minimum annular ring, 4mil.

For high-frequency and high-density PCBs, multi-layer aluminium PCBs can be made with up to 24 layers and a minimum trace or spacing as small as 4mil.

PCBCart can make aluminium PCBs with board thickness from 0.8mm to 5.0mm and a maximum size of 610×610mm; surface finish encompassing HASL, lead-free HASL and ENIG and various solder mask colours.

Contact:
PCBCart
Floor 3rd/4th, Building #1, NO.163
Wu Chang Road, Yu Hang District, Hangzhou, China 310023 **Tel:** +86 571 87013819
Web: www.pcbcart.com

Electrolube's New Generation of High-Performance Resins

Electrolube, the global manufacturer of electro-chemicals, will shortly launch five key new resin products for automotive, electronics and LED manufacturers.

ER2223 is a black, very high temperature, stable epoxy resin with a wide operating temperature range of -40 to 180°C and is designed to meet automotive under-bonnet requirements.

ER2224 is a thermally-conductive epoxy resin system, featuring an improved method of cure, high thermal conductivity and good thermal cycling performance. It is also suited to automotive applications and LED lighting units.

ER4002 is a flame-retardant epoxy resin with excellent electrical and high temperature performance and an operating temperature range of -40 to +150°C. The resin is suitable for the encapsulation of delicate electronic and electrical components and features low mixing viscosity and good flow characteristics.

New polyurethane resin systems include UR5638, a tough, low exotherm resin, which provides a clear, transparent finish. UR5638 is particularly suitable for encapsulation of larger LED lighting units.

UR5639 is a low viscosity, low hardness resin, transparent with a high level of flexibility.

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SERVICEMAN'S LOG

Dave Thompson*

Two crook MacBook Pro laptops

A failing battery pack is a fact of life for laptops once they're more than a few years old. Most aging batteries simply fail to hold a charge but some can fail catastrophically and damage the laptop's case in the process.

Items Covered This Month

- Battery problems in a MacBook Pro laptop
- Vintage AWA B&W TV set
- Denon twin-drawer CD player
- Fan cooling for a Sony LCD TV

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
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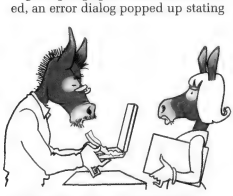
A few weeks ago, a long-standing customer called to ask if I would have a look at a couple of malfunctioning Apple Mac laptops belonging to his daughters. While he knows I focus mainly on Windows-based computers, he was enquiring on the off-chance that I might at least give them a quick once-over and perhaps even get them working again.

As this chap is a loyal customer of mine, I couldn't really say no and one of his daughters duly brought the two computers in to the workshop. Both were Apple MacBook Pro laptops and one of them looked as if it had been run over. I immediately assumed (even though I know assuming makes an "ass" out of "u" and "me"), that it had been dropped and I opened the conversation with that observation.

The young lady, who was the worried owner of the bent MacBook, was adamant it hadn't suffered any such event. This puzzled me, so I asked for more information. She told me that she was working with it the day before and it had just stopped working by turning itself off. She had managed to get it going again but when it booted, an error dialog popped up stating that the date and time were incorrect. It then died again but not before she'd observed that it hadn't automatically logged onto their WiFi network, which it usually did on start-up.


I IMMEDIATELY ASSUMED...

After that, she couldn't get it going again and thinking that the battery might be flat, she put it on charge and went out to do some chores. When she returned just a couple of hours later, the laptop's case was twisted and distorted and the touchpad assembly was protruding from its enclosure, as if it had been punched out from the inside.

The other machine belonged to her sister and it too had ceased working properly, though this one had the infamous Mac grey screen of death, indicating an issue with either the operating system or the hard drive.

The two machines were identical devices around four or five years old and apart from the obvious damage to one machine, both appeared to have been very well looked after. By now, I was keen to find out what had happened to them, especially the damaged one. That one had really piqued my interest.

One of my initial thoughts was some kind of paranormal event. OK, I'm just kidding but it did fit – a laptop goes from happily working to physically ruined within a matter of hours, without anyone so much as touching it. And there's even a teenager or two in the house to act as a "focus" so what else could it be?

Of course, in the real world there's a rational explanation for everything and I'll wager that many readers have already guessed what had happened here. I'd heard of it many times in the past but had never previously encountered an actual "live" case in the workshop. And that's surprising, given the number of years I've been doing this stuff.

As with all Macs, the internal circuitry is accessed by first removing the plate aluminium back (or base). True to form, there were a dozen tiny (but different-sized) screws holding the base on and one has to take note of their positions and be careful not to swap them around during re-assembly.

Unfortunately, because the base on this laptop was twisted and seriously puffed up, removing the screws was an act in itself. I had assumed that as soon as the tension on the screws caused by the warped case overcame the strength of the remaining threads holding the screws in, everything would let go and the threads would be stripped or otherwise damaged. So, to counter-act this force (and prevent further damage), I maintained a lot of downwards pressure on the screws with the driver until I felt them clear the threads. Only then was the case allowed to slowly pop open.

However, after the first couple of screws had been removed this way, instead of the pressure decreasing, the warped back was putting even more tension on the remaining screws. As a result, I now used elephant tape (I'm assured no elephants were harmed in the making of this tape) to bind the case together and take the tension while I removed the remaining screws, adding a strip of tape as each screw came out.

With the back off, it was patently

obvious what had happened; the battery, which takes up almost the entire bottom third of the area inside of the case, had become seriously distended. In fact, the plastic case that usually held the individual cells together had completely ripped open, with a couple of the cells inside the opened package looking like small pillows.

These two cells are usually about 4mm thick; now they measured 40mm! They were at the centre of the 6-cell package and it appeared that they were the only ones that had failed in this manner and had caused all the internal pressure.

The chassis of this laptop is made from cast aluminium, while the case components are sheet aluminium and plastics. When these are sandwiched and screwed together, the result is a very strong unit but when the cells began expanding, they had nowhere else to go but outwards.

Basically, they took the path of least resistance, which explains the distorted chassis and pillowed bottom. Furthermore, because the touchpad assembly sat immediately above the battery, when the cells beneath swelled, the touchpad simply popped straight up and out through the hole it usually sits in.

Battery mounting

The plastic frame of the battery locates into the chassis with embedded tabs along one side, while three screws on the other side secure it in place. A sticker warns users not to remove the battery, something a bit tough to comply with in this case!

Since the battery's plastic enclosure had no chance of containing the innards when they "went off", it simply snapped apart at the weakest points. The mounting lugs had broken off from the case and were all still held fast to the chassis, left behind when the rest of the plastic case went west. To make matters just that bit more complicated, the screws were those annoying anti-tamper types that many manufacturers love so much.

If you want to work on Apple products, then you'd better have a good set of specialised screwdrivers. That's because Apple uses lots of different anti-tamper "security" screw types. In this instance, the screws holding the back on (and those used in other locations inside the device) are tiny and appear to be a type of Frearson-head screw, similar to a very narrow Phillips style head. A small Phillips driver can usually remove them without making too much of a mess of the screw.

By contrast, the anti-tamper screws used to hold the battery in are a variation of the Tri-wing type, called a Y1. I've seen cases where people have mangled Tri-wing screws by using non-Tri-Wing bits to get them out, so it's obviously better to use the correct bit, especially if they are in as tightly as these ones were. It amazes me that they deemed it necessary to hold the battery in with this type of fastener but that's Apple for you.

As an aside, sets of security drivers are inexpensive from the likes of Ali-Express and are a valuable addition to any serviceman's toolbox. It really is staggering to think of the number of anti-tamper screws one comes across during servicing. I've seen them used in all sort of products, including Blu-ray players, kettles, mobile phones and garden blowers; in short, anywhere the manufacturer doesn't want Joe Lunchbox messing around with their products.

Of course, determined DIYers won't let anti-tamper screws stop them from getting in and I've even seen cases where bloody-minded individuals have opted to physically break the case open rather than kowtow to these manufacturer-imposed restrictions. Either that, or they've completely mangled the screws while attempting to extract them.

In the past, I'll admit to having "seen the red mist" where such screws are concerned, because not having the correct bit to remove them really kills the natural flow of working on a job. The silly part is that I can always jump in the van and go and get a suitable bit. They are usually readily available, which defeats the purpose of using anti-tamper screws in the first place.

OK, back to the chase. Once the battery was out of the machine and stored safely outside, I began checking out the collateral damage. Fortunately, the thin aluminium back cover was easily coaxed back into shape with some careful manual tweaking and though the metal had stretched a little, it would sit flat enough once all the screws were back in.

These photos show the battery as it appeared inside the case (top) and after it had been removed from the case. It had swelled enough to distort the chassis and the back.

More worrying was the cast aluminium chassis. I assume that it's cast and then machined to add threaded holes and other anchor points. Of course, it could also have been C&C machined from a single billet of aluminium (I wouldn't put it past Apple) but I think that casting is more likely. There's no doubt the manufacturers make a beautiful job of making components for these machines and of course, this is one of the alluring features of Apple products.

The downside is that it makes them expensive to repair if any spare parts are required. To straighten out the warped chassis, someone would have to have the gear to remove the lateral twists and then the skills and tools to panel-beat things back into shape. However, no matter how good someone was at this, any repair would still be

Servicing Stories Wanted

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Please be sure to include your full name and address details.

obvious (and it would be expensive), making replacement of the chassis the only feasible repair option.

Touchpad repair

Repairing the touchpad was fiddly but successful. The assembly is self-contained and is mounted into the chassis using an aluminium locating tab on one side and two wafer-thin spring-steel strips on the opposite side, to provide a "button" feel for the device. A microswitch is mounted at the bottom centre of the touchpad and spring tension keeps the pad raised until someone presses on it to activate the button (Macs use a single-click system so there are no complicated twin-button assemblies to worry about).

The expanding battery had forced the touchpad assembly out of its chassis aperture, easily overcoming the resistance of the two thin steel hinges (or strips) which had partly folded back on themselves as the pad was ejected. These steel strips were each removed by undoing two extremely small screws and the spring steel then gently pushed back into shape.

Fortunately, no hard bends had been made in them. If there had been, they would have simply broken when straightened.

Once the spring strips had been reformed, they were refitted and the touchpad screwed back into place again. Some minor fettling then saw it operating properly again.

Buying spare parts from the local Apple agents is expensive and there is no need to do so. All the Mac parts one could ever want are available from our eastern friends via the Internet. As an example, a battery (an original Apple part) from a Chinese vendor cost me US$80 including shipping, roughly one-third the cost for the same part here. The chassis was a bit more expensive but still remarkably cheap compared to one from the local supplier.

Fortunately, nothing else was amiss and once these items had later been replaced, the owner was back "Instagramming" and "Facebooking" to her heart's consent. It really was just a matter of fitting the parts and making sure that all the different screws went back in the right place. Fortunately, a screw map is available from Apple to help with this.

Fixing the second machine

The second MacBook Pro machine was a bit more interesting but I'm not going to relate the boring resolution of the grey screen issue. The relevant thing here is that I initially decided to swap in the hard drive from the first machine (ie, the one with the battery problem). That way, I could quickly get this second machine going again. I could then replace the hard drive and the parts in the first machine when they arrived from overseas.

Anyway, I swapped the drive in and fired up this second machine with the back still off, to make sure it worked. It booted OK but the battery indicator showed only 10% remaining. Fortunately, the owners had supplied one of their chargers, so I plugged it in and went about my work.

My intentions were that once it had charged and was operating properly, the client could come and grab that one. Unfortunately, it didn't quite work out that way. I was sitting at my desk doing some important YouTube research when I suddenly heard an almighty CRACK! It sounded as if a machine had fallen from the bench and smashed the LCD panel but an anxious glance towards the direction of the noise soon revealed that it was still in place.

Mind you, that's difficult to tell at the moment as my workshop looks like a bomb has gone off in it. That's because I'm in the process of renovating my garage/workshops while I'm trying to run the business. Normally, I'm very neat and tidy.

On closer inspection, the charging MacBook was sitting at a funny angle and when I turned it over, I could see why. Its battery had just blown out its last set of cells and the cracking noise had been the battery's plastic frame giving way, similar to the first machine. After a quick underwear check, I whipped the charging lead off and removed the battery, before placing it outside with the other one.

I immediately suspected the charger but a call to the client quickly revealed that this wasn't the charger used with the first MacBook. What's more, a check with my multimeter indicated that the output voltage from the charger was spot on. So it looked like the charger was in the clear.

I began to smell a rat with the batteries. Fortunately, this laptop hadn't been damaged as badly as the first because with the back off, the "exploding" battery had somewhere to go. The touchpad still suffered but the chassis wasn't as warped as the first one.

I repaired the touchpad and got everything ready for when the spares finally arrived. It was all rather frustrating though, because it meant that neither machine could be repaired until the spare parts arrived.

A week later, while I still had those two MacBooks in the workshop, I got a call from a new client. She told me that she had just fired up her MacBook and it had given her a time and date warning and wouldn't connect to the WiFi. My alarm bells immediately rang

Vintage AWA B&W TV set

Vintage B&W TV sets and AM valve radios can be quite collectible these days. K. W. of Riverstone, NSW recently got two such sets going again . . .

I recently had to help a friend whose brother had died and who had kept all sorts of junk, including lots of TVs. In one room, there was an old 1970s Rank Arena colour TV that had a VHF turret tuner (no UHF). Normally, these are reasonably collectible but in this case the woodgrain vinyl had faded to white after some 40 years of exposure to an un-curtained window.

However, I wasn't really interested in the old Rank Arena. Instead, I was interested in what was sitting on top of it – an AWA P1 portable B&W TV dating from around 1965. These are now very collectible and many still give a first-class picture despite their age, often with the original AWV valves.

The P1 was an all-valve portable and was basically a full-size TV chassis crammed into a portable cabinet. Thanks to the full-power 6.3V heaters they used, their picture tubes lasted the distance, unlike the ones used in the all-transistor portables that came later.

Jim said I could have it as it was no good since the analog broadcasts had stopped and anyway, it had "no horizontal hold". Across four decades, I remembered that the most common fault in the P1 was a leaky 0.0068µF paper capacitor in the vertical oscillator circuit. I also knew that people invariably confused loss of vertical hold with lack of "horizontal hold".

Back home, I put it on my workbench and applied power. I could see that the valves were lighting up but there were no other signs of life, which usually meant that the HT fuse had blown. This is a common occurrence if such sets haven't been run for a few years and usually occurs because the power supply electrolytics need re-forming. The usual cure is to connect an ammeter across the fuseholder and then carefully bring up the mains voltage from zero with a Variac, while monitoring the current until it stabilises.

Sure enough, after half an hour or so, everything began to work and I was rewarded with a crisp snowy screen and a healthy hiss from the speaker. I hooked up my old TV pattern generator and yep, the vertical hold was way off and there was the dodgy 0.0068µF "Hi Qual" capacitor exactly where I remembered it ("Hi Quals" were basically a paper capacitor with a plastic case!).

I replaced this capacitor and the old AWA P1 then worked perfectly. I was even able to download a PDF of the complete 1965 model service manual but I didn't really need it. I fully expected it to start to play up after a couple of hours but remarkably, apart from dirty tuner contacts and a noisy volume control pot, the capacitor was the only real fault!

I then wired up the luminance output from a digital set-top box (STB) to the grid of the video amplifier valve and got a really good picture. The sound was just as easy; I simply wired the left and right audio channels from the STB in parallel to the volume pot.

The next time I went down to Jim's place I said, "Good news! I got your old black and white TV running". He was unimpressed because, as he said, "you'll still need a set-top box".

While I was there, Jim brought out his 1940s-era Mullard 5-valve radio. It was faulty and he wanted me to have a look at it.

Back home, I quickly discovered that it required two new 22µF 450V electrolytic capacitors and a few other minor parts to restore it to full working order.

Interestingly, a note had been attached to the back, detailing how the set had been repaired by a service centre back in 1986 – which would have been a bit of an ask even then. Oddly, they had changed quite a few capacitors but not the one you must always change: the grid coupler from the plate of the audio preamp to the grid of the output valve. It was still there when I got the set and leaking like the proverbial sieve!

and I advised her not to charge it but to give it to me (or someone else) so that the battery could be checked.

When she brought it around, a quick check of the back panel confirmed that it too had a swollen battery. It was enough of a coincidence for me to send a warning to my email database, recommending that owners of three to 5-year-old MacBook Pro laptops have the batteries checked out. It might just save them a lot of grief.

Denon twin-drawer CD player

DVD/CD players are dirt cheap these days so why bother fixing them? R. W. of Lismore, NSW didn't want to part with his Denon twin-drawer CD player so when it began playing up, he rose to the challenge and fixed it. Here's what happened . . .

I have had a Denon DN2000F MkIII twin CD player for many years. This is a rugged 2RU rack-mounting unit with a separate 2RU controller connected via a proprietary lead.

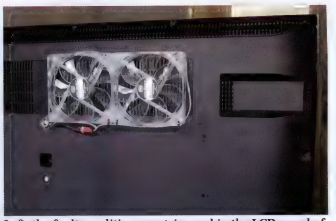
I first obtained this unit in the 1990s after being retrenched from the airline industry and deciding to try my hand at being a DJ. That wasn't a success but I kept the player as its cueing facility and variable pitch was something I had grown used to. It gave reliable performance until recently, some 25 years after purchase.

The problem was that disc drawer one would load a CD but would not cue it. However, assisting the drawer to close or turning the power off and then back on again (doesn't that "fix" everything these days?) with a disc inside allowed it to cue and play normally.

When listening to the drawer operate, it was obvious that the transport motor was running for a short time after the drawer either closed or opened, so I suspected that the limit switches either weren't being actuated or had developed a fault. Fixing it wasn't urgent and so I put up with this minor fault for quite some time, preferring to use drawer two instead.

Eventually though, drawer two also started playing up. In this case though, the transport motor was stopping when the drawer reached the open or close limits while being assisted. This was the impetus I needed to take it apart and see what the problem was.

After dismantling the unit, which appeared to be well-made, I inspected the PCBs for bulging electrolytics and discoloured components and found



Left: the fault condition was triggered in the LCD panel of the Sony set about 40 minutes after switch-on. Fitting a couple of fans to the rear cover helped cure the problem.

Fan-Cooling For A Sony LCD TV

Cooling fans were commonly used in the plasma sets of yesteryear but in this instance, retrofitting fans to a 132cm Sony LCD TV saved it from the scrapheap. G. S. of Castle Hill, NSW was the retrofitter . . .

The Sony KDL52Z5500 LCD TV was a top-of-the-range model costing over $3000 back in 2009. However, after just five few years of use, the 132cm LCD panel in my set suddenly began giving trouble.

Initially, the problem showed up as a narrow vertical flickering band on the lefthand side of the screen at power up. This would then disappear after a few minutes as the set warmed up and so the fault was initially considered trivial.

It didn't stay that way though and over the next few weeks, the switch-on fault progressively became more serious. It eventually got to the point where the entire lefthand side of the screen would take on a reddish hue with very dark shading, picture tearing and vertical ghosting. It would then invariably come good and display a perfect picture after 30 or 40 minutes (when the panel had warmed up) until one day it didn't, despite leaving it running for several hours.

This sort of problem is often due to faulty "tab" connections between external flat ribbon cables and the transparent electrodes just inside the edge of the LCD panel. With repeated thermal cycling, the bonding contacts inside the LCD can become intermittent and a panel failure of this sort generally means that the set is a write-off.

However, there's one neat trick you can pull to try to save it: remove the metal frame that runs around the outside of the LCD panel (and secures it in position), run draught excluder around the inside of the frame and reassemble it. The idea here is that the draught excluder applies extra pressure to the tabs when the metal frame is fastened back into place and will hopefully "cure" the problem.

This fix initially worked a treat for my Sony set, as detailed in Serviceman's Log in the November 2014 issue. However, after a few months, the problem reappeared but with one important difference: the timing of its appearance had been "transposed". Now, instead of the fault occurring when the set was cold, it was appearing about 40 minutes after switch-on, after the panel had thoroughly warmed up.

What was frustrating was that the picture was perfect for those first 40 minutes or so. After that, the dark shading, ghosting and reddish hue would suddenly appear and it

none. I then removed drawer one and located a small PCB which held the two limit switches and interfaced them to a flat lead with a polarised header.

There were no other electronic parts on this board other than the switches. One was a very small unit similar to a microswitch and this was the close-limit switch. By contrast, the open-limit switch consisted of a flimsy pair of contacts in a rubberised cover that was actuated by a slider on the drawer unit (which also contained the end-of-travel buffer springs).

Both switches measured greater than 500Ω when closed, so I applied some contact cleaner, reassembled the unit and tested it. That fixed it but the fault was back less than a week later.

I tried looking everywhere on the internet for a replacement board or, failing that, replacement switches but to no avail. I then emailed Denon but was told that this player was no longer supported. A supplier in the UK had complete drawer and laser assemblies but at £300 (about $550), that was too much to spend, especially as I needed two.

Then I had a brainwave. If I could replace the existing switches with suitable microswitches, I just might be able to resurrect the unit. After a brief search, I found some at Jaycar (Cat. SM1038) and bought four at just $4.95 each to try.

After removing the old switch PCB, I actuated the existing switches and checked the resistance. The open-limit switch was now open-circuit but the close-limit switch was OK, although the drawer motor still ran when the drawer was closed. I gave this no further thought and decided to replace both. And that's where the fun began.

The new switches were several times larger than the old ones and it was difficult to determine where to mount them. After much trial and er-

was so bad that the picture was unwatchable.

Clearly, the fault was heat-sensitive; the LCD panel had to get nice and warm in order to trigger it. So what could be done about it? The obvious answer was to somehow keep the panel from reaching the critical "trigger" temperature and using computer fans to extract the set's warm interior air seemed to be the way to go.

After some hunting around on the internet, I came across a CoolerMaster 120mm case fan from a local retailer that seemed ideal for the job. It ran at 1200 RPM, had a quoted noise level of just 19.3dBA (so it would be nice and quiet) and came in a dual pack for just $19.00. Mounted together side-by-side, the two fans would be just large enough to cover a large ventilation panel towards the top righthand side of the rear cover.

Inside or outside

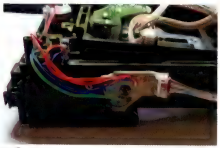
When I got the fans home, the first thing to do was to figure out whether to mount them inside the rear cover or on the outside. After some thought, I decided to mount them on the outside and power them from an external 12V DC plugpack. That way, they wouldn't block the airflow to the horizontal ventilation slots at the very top of the rear cover.

With that decided, I undid the umpteen-dozen screws that secured the rear cover, laid it flat on the floor and used one of the fans as a template to drill two diagonally-opposite mounting holes. This fan was then secured in position using Nylon M4 x 15mm screws, nuts and washers, after which the second fan was mounted in position, butted hard up against the first. Nylon mounting screws were used at all four mounting positions because I didn't want metal screws protruding into the chassis, with the risk that they might contact a high voltage or short something out.

Once the fans were in place, I replaced the rear cover, then sorted through my spare parts and found a 2.5mm DC socket. This was mounted on a small Perspex bracket which in turn was attached to an outside corner mounting hole of one of the fans. The DC socket itself was wired to two paralleled 3-pin polarised pin headers and the two fans then plugged directly into these headers. Several cable ties were then used to tidy up the wiring and secure it all in place.

Now for a power supply. A quick ferret around in my workshop soon turned up a 12V DC plugpack supply rated at 600mA – more than enough to power the two 160mA fans. I plugged it in, switched on and the two fans whirred into action. And just as their noise specification indicated, they were nice and quiet – so quiet in fact that you weren't aware they were running from a normal viewing position.

So did the idea work? It sure did – well almost! The set now runs for 3-4 hours before giving trouble, as opposed to the measly 30-40 minutes before the fans were fitted. Running the fans at a higher speed (eg, by increasing the supply voltage by 1-2V) or adding extra fans would probably solve the problem completely.



Substituting microswitches for the original limit switches and relocating the switch PCB helped get a Denon twin-drawer CD player working again.

ror, I settled on the two positions and after soldering fly-leads to both, temporarily secured them in place using a dab of contact adhesive. I then operated the drawer manually and the positions seemed correct.

It was then that things went pear-shaped quickly. To gain access, I had removed the cover to the drawer which held the top-clamp for the disc when the laser is in position. This cover also holds the drawer mechanism in place and while I was testing the switches, the drawer fell out and took one of the sliders with it.

I tried to get the mechanism back together but just couldn't find the right position. I wished then that I had a time-machine to take me back to just before it fell apart. However, perseverance eventually paid off and somehow it all eventually clicked back into place.

Operating the drawer now revealed that the drawer rack was not correctly aligned with the drive pinion and wouldn't run to its full travel. The drive mechanism winds the drawer in and on reaching the inner limit, a mechanical disconnect operates and the drawer motor then drives the laser assembly into position before finally operating the close-limit switch. After more fiddling, I finally got it right but don't ask me how.

The next day, I verified the switch operation and applied a 2-part epoxy adhesive to permanently secure the microswitches. The fly leads were then soldered to the switch PCB which was trimmed and encapsulated in clear heatshrink tubing and relocated to the side of the mechanism. It all looked good, so I reassembled the player and put it through its paces.

It failed and as can be imagined, I was rather crestfallen. Neither of the switches was being activated. The open-limit one was out by about 1mm but the close-limit switch wasn't activating at all. The drawer would close but the laser assembly wasn't lifting into position.

So I had another fault that I had failed to notice and that was that the motor didn't seem to have enough torque to operate the laser lifting mechanism due to a slipping belt. So why hadn't I noticed the belt? It couldn't possibly be OK after 25 years and indeed it wasn't.

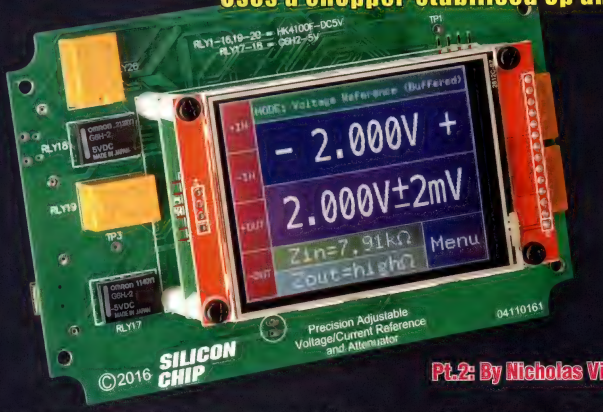
I went back to the internet to see if I could find spares and eventually came across a supplier in Portugal from whom I bought two generic 25mm diameter 1.2mm belts for under $10, including postage.

These were installed and after a slight adjustment to the open-limit switch actuator, the player was reassembled and tested. That was it – both drawers now worked faultlessly, although drawer two may also need to have its limit switches replaced sometime in the future.

And so, for an outlay of less than $30, the old Denon DN2000F CD player was given a new lease of life and may well last another 25 years. Will CDs still be around in 2041 and if they are, will I still be around to use them? SC

Precision Voltage & Current Reference With Touchscreen Control

Uses a chopper-stabilised op amp



Pt.2: By Nicholas Vinen

We introduced this instrument with its comprehensive touchscreen control in the October issue. It is a first for SILICON CHIP in that is is a test instrument with no physical switches or knobs to control its functions; everything is done via the touchscreen. In this second and final article, we give the construction details and provide all the testing and operation instructions.

VIRTUALLY ALL the components are mounted on a single PCB coded 04110161 and measuring 140 × 85mm. Fig.3 shows how the components are fitted in both sides of the board. All the SMDs are mounted on one side while the through-hole components and the LCD BackPack module go on the other side. The only off-board components are the four insulated banana sockets. The PCB assembly and all four banana sockets are mounted on the lid, with short lengths of stiff wire joining the sockets to the board.

Start by fitting the SMDs. The only slightly tricky parts are voltage reference REF1 and the USB socket (micro or mini, depending on which you have decided to fit). These have the most closely spaced pins. However, there are only a few pins on each and the other components have much more generous spacing, making them quite easy to solder.

Start with REF1. Use a magnifying glass and a good light to identify the pin 1 dot on top of its package and place it on the PCB near its pads, with pin 1 closest to the adjacent board edge. Place a little solder on one of its corner pads, then heat that solder while sliding the part into place. Check that all its leads are over their associated pads; if not, reheat the solder joint and gently nudge it into place.

Alternatively, having tinned one of the pads, you can carefully line up the IC and then press down gently on it while heating the solder on that pad to let it "sink in". Either way, you should now have the part tacked down and properly aligned with all of its pads. You can then proceed to solder the remaining pins. This is easiest if you first apply a little flux paste to the pins.

Don't worry if you bridge any of the pins with solder; simply add a little flux paste and use solder wick to remove the excess solder. When finished, refresh the solder joint on the pin you first used to tack the part down, either by adding a little flux and heating it (the preferred method) or by adding some fresh solder.

Clean off any flux residue using flux cleaner or alcohol (eg, methylated spirits or isopropyl alcohol) and carefully check all six leads to ensure that they have proper fillets and no bridges. Assuming you're happy with that, move on to solder the remaining ICs (IC1-IC6 and REG1) using a similar technique. If you can't locate a pin 1 dot or divot on any of these, check for a bevelled edge; pin 1 is on that side.

Discrete semiconductors

Next, move on to the smaller discrete semiconductors, ie, D1-D4, Q2, Q3, ZD1 and ZD2. Note that with the exception of D1, these are all in essentially identical packages so don't get them mixed up. All you need to do is tack down one pin as above, check the placement and then solder the remaining pin(s).

Now move on to the resistors and capacitors, using a similar technique. None of them are polarised. The resistors are labelled with their value in a shortened code (eg, 22kΩ = 223 or 2202) however you may need a magnifier to read them. SMD ceramic capacitors are not labelled. Note that the three 10µF capacitors may be larger than the others and the pads provided are more widely spaced to suit. The 0.1Ω resistor is larger again but a similar technique can be used, although you might need to hold the iron on the joint a bit longer to produce a good joint.

The smaller inductor (L2) can be fitted in the same manner as the resistors and capacitors. And while a similar technique is required for L1, its much larger thermal inertia presents some challenges. Be sure to spread a little flux paste on both pads before starting. Also, when you slide the part onto the pad with the molten solder, you will find it solidifies as the inductor heats up and it will be several seconds before you can finally move the part into its correct location.

Lastly, when applying solder to the second pad, you will need to heat it for a few seconds before a good solder joint will form.

Now fit Mosfet Q1. Start by spreading a thin smear of flux paste on the large pad, then add solder to one of the smaller solder pads and slide the part into place, as with the other components. After that, solder the other two small pins before turning your attention to the large tab. As with L1, it will take a few seconds to heat the

Parts List

1 PCB, code 04110161, 140 x 85mm
1 Micromite LCD BackPack module
1 UB1 jiffy box (157 x 95 x 53mm)
1 black laser-cut lid to suit jiffy box (optional)
2 red panel-mount binding posts/ banana sockets (IN+,OUT+)
2 black panel-mount binding posts/ banana sockets (IN-, OUT-)
3 0.9mm PCB pins (TP1-TP3) (optional)
1 47µH 6x6mm SMD inductor (L1)
1 220µH 3.2x2.6mm/1210 SMD inductor (L2)
18 HK4100F-DC5V-SHG SPDT relays (RLY1-16,RLY19,RLY20)
2 G6H2-5V DPDT relays (RLY17,RLY18)
1 SMD mini USB type B connector (CON1a) and/or
1 SMD micro USB type B connector (CON1b)
1 18-pin low-profile female header (or cut down 40-pin dual-wipe DIL socket) (CON2)
1 18-pin female header (or cut down 20+ pin female header) (CON2)
1 200mm length 0.7mm diameter tinned copper wire (or four component lead off-cuts)
4 M3 x 25mm machine screws
4 M3 x 15mm Nylon tapped spacers
4 3mm ID 6mm OD 1mm thick Nylon washers

Semiconductors

4 TPIC6C595 8-channel SPI relay drivers, SOIC-16 (IC1-IC4)
1 ADA4522-4ARZ quad precision op amp, SOIC-14 (IC5)
1 LM358, SOIC-8 (IC6)
1 MAX6071-2.5 precision 2.5V reference, SOT-23-6 (REF1)
1 CS5173 boost regulator, SOIC-8 (REG1)
1 BSP030 N-channel Mosfet, SOT-223 (Q1)
2 BC846 NPN transistors, SOT-23 (Q2,Q3)
1 5.6V SOT-23 zener diode (ZD1)
1 39V SOT-23 zener diode (ZD2)
1 DB2W60400L 60V 2A Schottky diode (D1)
3 BAT54S dual serial Schottky diodes (D2-D4)

Capacitors (2012/0805 X7R 50V unless stated)

3 10µF 50V X5R 3216/1206
4 4.7µF 6.3V X5R
1 1µF 16V X7R
9 100nF
1 10nF
2 47pF 50V C0G/NP0

Resistors (0805 1% unless stated)

2 270kΩ	1 3kΩ
1 56kΩ	2 2.2kΩ
2 47kΩ	2 1.5kΩ
3 30kΩ	6 1kΩ
51 12kΩ 0.1%	3 100Ω
4 10kΩ	2 47Ω
1 4.7kΩ	1 0Ω

1 0.1Ω 1% 3W 2512

Note: a short form kit will be available for this project from the Silicon Chip online shop which includes everything except for the BackPack kit (available separately), box, tinned copper wire and optional PCB pins.

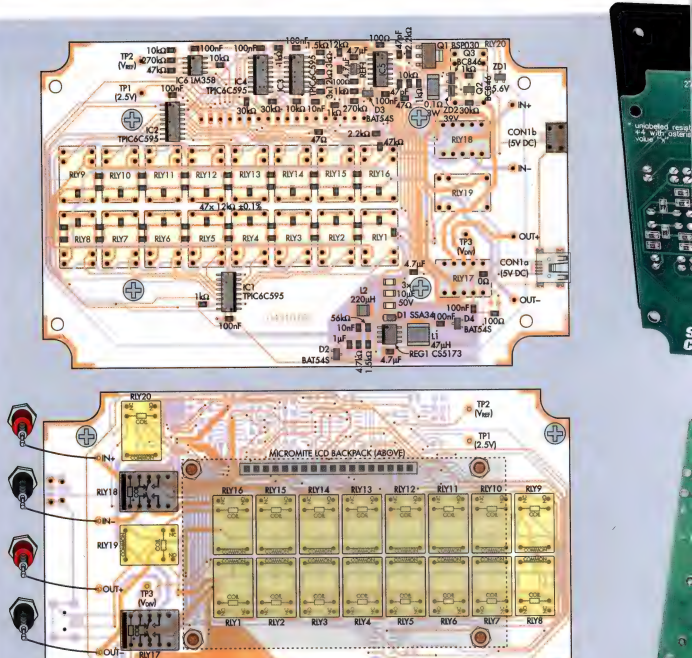


Fig.3: the parts layout diagrams for both sides of the main Voltage/Current Reference PCB. All SMD components go on one side of the board, as shown at top, while the relays and LCD BackPack are mounted on the other side. Only one of USB power input connectors, CON1a and CON1b, should be fitted. Note that the 18-pin female header that the LCD BackPack is plugged into actually consists of two stacked headers (see text).

part and PCB up so that they are hot enough for the solder to flow properly and form a good joint.

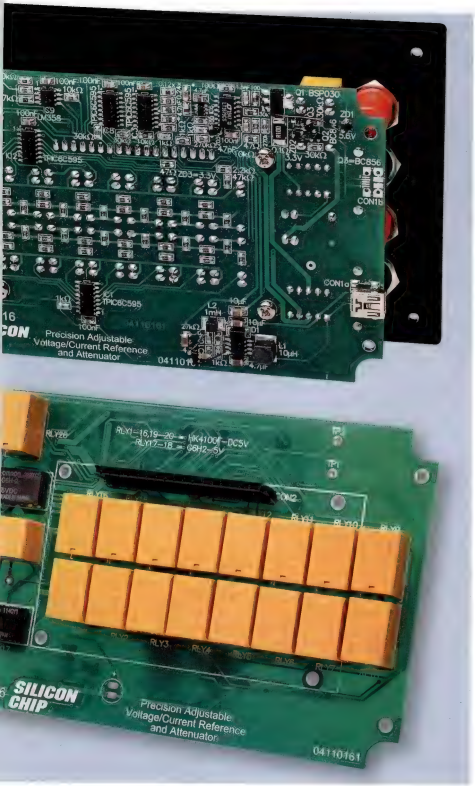
The final SMD part to fit is either CON1a or CON1b (one of the USB sockets). **Normally, both would not be fitted, as plugging them both into two different USB sockets would potentially damage one or both of the power supplies.**

Decide which one you want to use, then solder one of its mounting lugs to the board, using a similar technique as before. Make sure all the small pins are properly aligned over the pads before soldering the other mounting lugs and finally, the pins themselves.

You will probably need to apply flux and some solder wick to remove any bridges which form, as the pins are closely spaced. We've elongated the pads for both connectors to make this easier.

Assembling the BackPack

If you haven't already done so, you will need to assemble the Micromite LCD BackPack, as described in the February 2016 issue. This is a pretty quick job as it only involves a dozen



or so through-hole components. Note that this project was not designed to use the Micromite Plus LCD BackPack (described last month); it requires multiple 5V-tolerant pins, which is one of the few incompatibilities between the two. So for now, you will need to stick with the regular LCD BackPack.

Note that the BackPack is available as a complete kit from the SILICON CHIP Online Shop and you can even get it with the BASIC software for this project pre-loaded – see **www.siliconchip.com.au/Shop/20/4021**

One small change that we suggest you make while building the LCD BackPack is to use a right-angle header for CON1 (power and console), with the pins projecting out the side of the module, as shown in our photos. That makes it easier to supply power for testing and also provides access to the serial console, should you need it.

Once you've assembled the BackPack PCB, mount the LCD touchscreen in place. If you have purchased a kit which already has the correct software loaded, then you can test it by applying 5V power to the board and check that the display comes up correctly. The software should detect that the main board is not attached and display a message indicating this. You can now test the touch function by touching that message to dismiss it.

If you don't have a pre-programmed chip, there are two ways to program it. Firstly, you can download the HEX file for this project from the SILICON CHIP website and load this onto your PIC32 using a PICkit 3 and Microchip's MPLAB X IPE (Integrated Programming Environment). You can then plug the chip in and proceed as per above, however, you need a PICkit 3 to do this, plugged into the ICSP header on the BackPack board.

Alternatively, if you have a PIC32 programmed with MMBasic (or you can program one), you can then plug this into the LCD BackPack, power it up, connect it to your PC using a USB/serial converter (as described in the February 2016 issue) and then set it up using the free MMChat software.

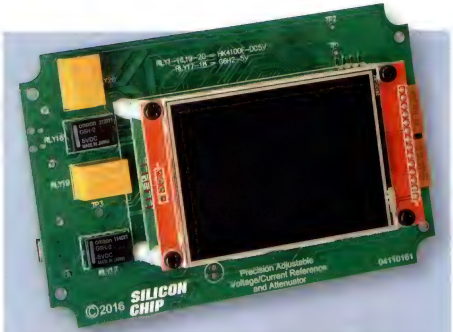
To get it going, you will need to set up the TFT and touch interfaces (also described in the February 2016 issue), then download the BASIC source code for this project from the SILICON CHIP website and upload it to the Micromite chip, as detailed in the panel on page 70.

Through-hole parts

Now flip the board over and fit CON2. This is an 18-pin low-profile female header which can be cut from a 36-pin (or larger) DIL socket. 40-pin sockets are probably the most common part which can be used.

Carefully separate one of the pin strips from the rest of the socket by cutting the plastic cross-braces with a side cutter. Trim off any large projections and cut off any excess pins so that you are left with 18 (be careful not to cut the 18th pin or you may have to throw it away and start again).

Now, feed the four M3 x 25mm machine screws through the BackPack mounting holes on the main PCB (heads on the SMD component side)



The Micromite LCD BackPack module is plugged into the header socket on the relay side of the PCB and is secured in place using M3 x 15mm tapped Nylon spacers and machine screws (see text).

and place one of the 1mm thick Nylon washers over each screw shaft. Screw a 15mm tapped spacer over each shaft until it is almost tight.

Next, detach the TFT module from the BackPack PCB and unscrew the four tapped spacers. That done, plug the full-height 18-pin female header into the low-profile header you made earlier (from the DIL socket) and plug that assembly onto the 18-pin male header on the underside of the BackPack PCB. Push it all the way home.

Now place the BackPack PCB over the four screw shafts sticking out of the tapped spacers and lower it down so that the pins of the female header go through the holes in the corresponding pads on the main board. That done, screw the 9mm tapped spacers removed from the BackPack earlier on top of the remaining shafts in order to hold the BackPack PCB in place while you solder the female header to the SMD component side of the main board. Make sure it's sitting flat on the PCB before doing so. Now that the header has been soldered to the board, remove the BackPack PCB and its mounting screws and spacers and keep them until later.

Remaining on-board parts

Basically, the only components left to fit to the PCB are the 20 relays. The two G6H2 DPDT relays must be soldered with their pin 1 markings towards the nearest edge of the board, as shown in Fig.3. Make sure they are pushed down fully onto the board before soldering the pins. It's a good idea to solder two diagonally opposite pins and then check the relay is sitting flat before soldering the remaining pins.

The orientation of each of the 18 HK4100F relays is obvious, as they can only be inserted one way. Again, make sure they are pushed fully into the PCB before soldering.

Now you can re-attach the BackPack PCB, as you did before. Make sure that all the screws and spacers are done up tightly. But before plugging the TFT module back into the BackPack PCB, trim the 14 solder joints adjacent to the LCD screen as short as possible using sharp side-cutters so that they won't interfere with the lid later (these joints are for the 14-pin header which was supplied pre-soldered to the module).

You can now plug the TFT module into the BackPack and attach it to the Nylon spacers using the 6mm machine screws supplied with the BackPack kit. Don't lose the four extra Nylon washers or longer screws supplied with that kit as you will need them to attach the whole assembly to the lid shortly.

Testing

You can do some testing before proceeding to fit the unit into the case. It's a good idea to check that the unit's current drain is within the normal range when it's first powered up. A current-limited power supply is handy to have, but not strictly necessary. You can use any 5V supply capable of delivering at least 500mA, connected in series with a DMM set to measure amps.

It's easiest to make the supply connections to CON1 on the LCD BackPack module. Be careful that you make the connections properly, especially since there is no reverse polarity protection; check the labels on the BackPack PCB. The current drain should be around 50-200mA, depending on the setting of the backlight trimpot. If you get a reading much higher than this, switch off immediately because that suggests you have a short circuit or an incorrectly placed component somewhere on the board.

If you have an excessive current drain, you can troubleshoot further by unplugging the BackPack and briefly connecting a current-limited 5V supply across pins 1 & 2 of RLY17, with +5V to pin 1; pin 1 can be identified as having a square pad and pin 2 is adjacent. Without the BackPack attached, only a few milliamps should flow. Much more suggests that there is either a short circuit somewhere on the board (eg, due to bridged pins), an IC has been soldered with the incorrect orientation or one of the other parts is incorrectly installed.

On the other hand, if the current is too low then that also suggests that there is a problem, possibly with the microcontroller programming or soldering, or its bypass capacitors. Proceed with troubleshooting the BackPack module as per the instructions in the February 2016 issue.

Now is a good time to check that you have very close to 2.5V between TP1 and a convenient ground point, such as the shell of the USB connector. You should also find virtually the same voltage at TP2 at this point.

Once the micro has been programmed and the software is running, you should be able to further verify the operation of the unit. On power-up, you should be greeted with the initial screen shown in Fig.4. Touch the voltage display below the top bar and on the keyboard which appears (Fig.6), press "2" and then "V". Then press the line which reads "Zout=highΩ" at the bottom of the screen.

You should get the display shown in Fig.7 and immediately upon pressing at the bottom of the screen, you should hear the relays click and the

current drain will jump as the coils are energised. Now connect a voltmeter between the OUT+ and OUT- terminals at the left side of the board and you should measure very close to 2V. That verifies that the reference, divider ladder and relay drivers are all working properly.

You can now test the boost regulator and PGA by again touching the voltage setting just below the top bar and this time entering "4V". As soon as you've pressed the "V" button, the boost regulator will be enabled and the 5V current drain should jump again. Assuming all is well, you can measure 4V between OUT+ and OUT- and 5V (ie, Vref) between TP2 and ground. If you can access L2, you should be able to measure the voltage on either side of it, relative to ground, at around 39V. This is the output of the boost regulator.

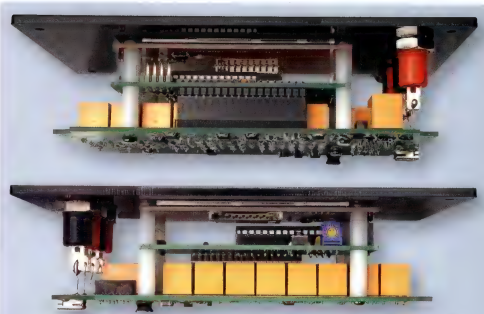
If you don't get 4V at OUT+ or you find the unit locks up or draws an excessive amount of current, you may have a problem with REG1 or one of its associated components. **But note that there is quite a large initial spike in the current drawn from the 5V supply when it starts up, so if you are powering the unit from a computer USB port, it may well detect this as a fault and shut the port down. So it's best to power the unit from a 5V charger or bench supply.**

Assuming it's all working so far, it's worthwhile doing one final check before putting the unit in its case and that is to test the operation in current reference mode. To do this, touch the top of the screen and select "Current Reference", then press the box below this and enter "10mA", then press on "Zout= off" at the bottom of the screen to turn it on (Fig.8).

It's then just a matter of connecting an ammeter set to milliamps mode between the output of your 5V supply and the OUT+ terminal. You should get a reading close to 10mA±0.1mA (plus the tolerance of your ammeter). Basically, if the reading is between 9.5mA and 10.5mA then chances are everything is working correctly.

Case preparation

The case requires 10 holes in total: one in the side for the USB power supply socket, one rectangular cut-out in the lid for the touchscreen, four 3mm holes in the lid for mounting the whole assembly and four larger holes in the lid for the insulated banana input/output sockets.



These two views show how the Micromite LCD BackPack module and the Voltage/Current Reference relay PCB are stacked together with the front panel.

We're not going to go into detail here because by far the simplest and neatest approach is to purchase a laser-cut panel from Silicon Chip to replace the existing case lid. These are made from 3mm black acrylic with a matte surface on the top side and the holes are all neat and accurately cut. The panel is sized to fit exactly on a standard UB1 jiffy box and uses the same mounting holes for attachment.

Also, the four banana socket holes in the laser-cut lid are profiled for a snug fit and to prevent accidental rotation of the sockets. The only disadvantage compared to the lid supplied with the case is that the corner screw mounting holes are not recessed, so the screw heads will project slightly above the lid. Also, you may need to use longer self-tapping screws than those supplied with the case (depending on the manufacturer). Still, we think this is the easiest approach that most constructors will adopt.

If you still want to cut the holes in the lid yourself, download the drilling template PDF from the Silicon Chip website and use this as a guide.

Once you have prepared the lid (or obtained the laser-cut version), attach the completed PCB assembly to its underside with 1mm thick Nylon washers between the top of the TFT module PCB and the back side of the lid. Attach the module to the lid using M3 x 8-9mm machine screws (ideally, black). Make sure that the touchscreen surface is flush with the top of the lid and that it hasn't caught on any plastic burrs or projections.

Now remove the retaining nuts from the four insulated banana sockets, push the sockets through from the top side of the lid and then re-attach the nuts on the other side. Do them up tightly. Make sure that the red and black sockets are in the correct locations – if in doubt, refer to the photos in this article.

Next, feed short lengths of tinned copper wire through the banana socket tabs and bend them over to go through their corresponding pads on the PCB. Solder these wires at both ends to complete the electrical assembly.

Final assembly

The only additional hole is the USB socket access hole, on the side of the case. This cut-out should be approximately rectangular in shape (12mm wide, 6mm high), with its upper edge positioned 32mm down from the top edge of the box. Its exact location depends on which USB socket you have fitted.

The easiest approach is to download the drilling template from the Silicon Chip website, cut out the side panel, attach it to the side of the UB1 jiffy box case and then drill a series of small holes around the inside of the appropriate cut-out. Knock out the

Uploading The BASIC Code To The BackPack

The simplest approach here is to purchase a pre-programmed PIC or, if starting with a blank PIC, flash it with the supplied HEX file which includes MMBasic along with all our code. Alternatively, if you are starting with a regular LCD BackPack kit or you want to modify the software, here's how you load the BASIC code.

First, program your PIC32 with the MMBasic 5.2 firmware and establish a serial console connection using a USB-serial adaptor. You will need to set up the display and touch panel as detailed in the February 2016 article on the LCD BackPack. Note that the BackPack (and, if attached, the main board) are powered from the PC during this process.

Then you need to load "SCVoltCurRef_Library.BAS" into the Micromite, which contains the fonts. Having downloaded this from the SILICON CHIP website, grab a copy of Jim Hiley's Windows/Linux "MMEdit" program. It is freeware and available from **www.c-com.com.au/MMEdit.htm** For Windows, download the setup file called MMEdit.exe and run it. It will work on any Windows version since XP.

Run MMEdit and open the BASIC file mentioned above. Next, ensure the "Auto crunch on load" option in the Advanced menu is selected and set up the COM port to communicate with the Micromite by selecting the "New . . ." option under the Connect menu. You can then click the "Load and run current code" button, rightmost in the toolbar under the menu (with the icon that looks like a blue stick figure running while holding a torch). You should get a progress dialog and the upload will take around 30 seconds.

If it fails, close this window and re-check the COM port settings; make sure you don't have the port open in another program.

Once the upload is complete, the MMChat console window should automatically appear. You can then execute the "LIBRARY SAVE" command (note: if you have previously done this, you will need to run "LIBRARY DELETE" first). After a brief delay, it should display the MMBasic prompt (>). You can verify that the code was saved by issuing a "MEMORY" command, which should yield a response like:

```
> memory
Flash:
 0K (0%) Program (0 lines)
 14K (24%) Library
 46K (76%) Free
```

Now open the file "SCVoltCurRef_Main.BAS" file (which is supplied in the same ZIP as the BASIC file loaded earlier) and, again ensuring that the "Auto crunch on load" option is enabled, upload that to the PIC32. The MMChat window should appear once this is complete. You can then type in "OPTION AUTORUN ON", press enter, then execute the "RUN" command to start the program.

Now unplug the USB lead and proceed with the remainder of construction/set-up.

centre plastic section and file it into a rounded rectangle shape, then clean off any swarf and plastic pieces and drop the PCB assembly down into the case temporarily to make sure the USB socket lines up with the hole.

Using it

There are four basic ways to use the unit: (1) as a divider/attenuator, (2) as a voltage reference, (3) as a current reference or (4) as a resistance reference (albeit with a rather limited range).

The first step, once the unit is up and running, is to select the mode and that's done by touching the line right at the top of the screen. A list of six available modes appears and you select the one you want by pressing on it (see Fig.5). The two extra modes allow you to enable or disable the output buffering in the attenuation and voltage reference modes. Normally you'll want to enable the buffering to reduce the chance of output loading affecting the accuracy of the unit, however, you need to use unbuffered mode for input voltages outside the range of 0-38V (up to ±60V).

Having selected the mode, the next step is to set the required parameter by pressing on the display area just below the top mode bar and then using the keypad which appears. Taking each mode in turn, this parameter is:

- **Divider/attenuator mode:** the attenuation factor between zero (100% attenuation) and one (no attenuation). There are a number of different ways to set this. You can enter a decimal number between zero and one, or you can enter a fraction like "1/2" or "2/3" (decimals are allowed in both the top and bottom parts), or you can enter a divider ratio such as "3:1" which operates like a resistive divider. In this case, it would operate similarly to a 3kΩ/1kΩ divider in that it is equivalent to a ratio of "1/4" or "0.25".

  You can also enter a value in decibels (including decimal places), in which case, the attenuation factor will be calculated based on that. For example, entering 20dB is equivalent to entering "1/10" or "0.1" (see Fig.9).
- **Voltage reference mode:** the desired output voltage, entered in either V or mV. The range is either 0-37V or 0-37000mV. You can also enter a fraction such as "2/3V".
- **Current reference mode:** the desired current to sink/source, in either A or mA. The range is either 0-5A or 0-5000mA. You can also enter a fraction such as "1/20A".
- **Resistance reference mode:** the desired resistance, between 3.5kΩ and 114kΩ. Enter the value desired, in either kΩ or Ω but note that the actual resistance you get (which will be displayed on the screen later; see Fig.10) may not be exactly what you have entered. For values in the range 4-12kΩ, chances are you will get the exact value you entered or very close (off by maybe one ohm). For 3.5-4kΩ and 12-18kΩ, expect a value within a few ohms of the target. Above 18kΩ, the error increases to around ±10Ω at 22kΩ, ±50Ω at 33kΩ and up to 1kΩ or more, above 55kΩ.

Having entered your desired parameter, the actual output that you will get will be shown just below it. This display is most helpful in divider/attenuator mode as you can see the entered value (which may be in decibels or a fraction), along with the equivalent decimal value below. However, in all modes, the tolerance figure may be helpful.

Towards the bottom of the screen, the approximate input and output impedances are shown. The output resistance is fixed and depends on the mode; it is normally either 0Ω (ie, a buffered output) or 2.4kΩ (the ladder output re-

Fig.4: assuming everything is working properly, this is what should appear on the LCD when the unit is first powered up.

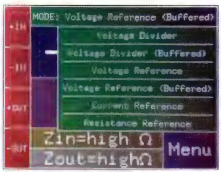


Fig.5: after touching the bar at the very top of the screen, you can select from the six different modes shown. here.

Fig.6: when you touch a value that can be changed, a keyboard like this appears. The keyboard layout changes to suit the value being entered.

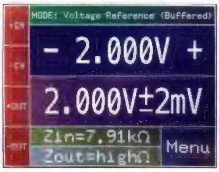


Fig.7: the unit has now been set as a 2V voltage reference with buffered output but the output has not been switched on yet, as shown at bottom.

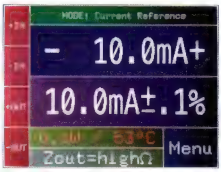


Fig.8: it is now operating as a 10mA current reference and the output is on. Note the always-present terminal labels at the left side of the screen.

Fig.9: in divider mode, the division ratio can be entered in multiple ways; in this case, in decibels (dB). The attenuation factor is shown below.

Fig.10: the resistance reference mode is somewhat limited; the selected resistance is shown at the top while the actual resistance is shown below.

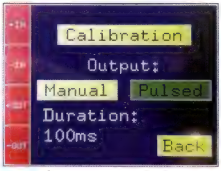


Fig.11: the set-up menu which provides access to the calibration menu and allows you to set up the output for manual or pulse mode.

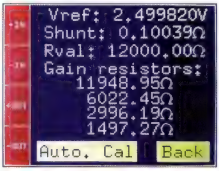


Fig.12: the calibration screen after pressing the Automatic calibration button. Note that the PGA resistors are now shown with the measured values.

sistance). Note that initially, this will show "highΩ" or "output off", indicating that the output is not yet switched on and you will need to press on this area to activate the output.

The input resistance also depends on the mode as well as the current parameter setting (ie, attenuation, output voltage, etc). It ranges from 3.5kΩ to 114kΩ, ie, the same range as available in resistance reference mode. This means that if you're using the unit to attenuate an external signal, depending on the attenuation factor, it may need to drive a load as low as 3.5kΩ. But you can always enter the required ratio and then check what the actual input impedance will be before proceeding.

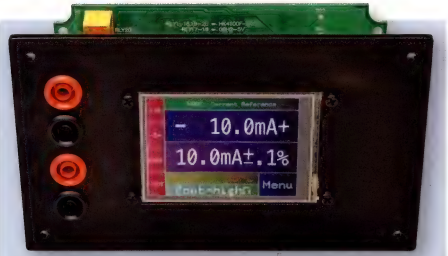
Note that most of the time, it's the reference voltage generator driving the ladder so the input impedance is only really important in attenuator mode.

While the unit is running, note also that on the left side of the screen, the inputs and outputs connections are shown so that you can always refer to these while wiring it up. Also note that the current mode and parameters are stored in non-volatile memory and will be restored when the unit is powered back up, however it will always power up with the output disabled.

Making connections

Connections are made as follows, depending on the mode:

- **Divider/attenuator**: the signal source is connected between IN+ and IN-, and the output is available between OUT+ and OUT-. An external connection between IN- and OUT- is required for correct operation.
- **Voltage reference:** IN+ and IN- are not connected internally. The refer-



The completed unit, prior to installation in the case. The two input sockets (IN+ & IN-) are at top left, while the output sockets (OUT+ & OUT-) are immediately below them.

ence voltage is available between the OUT+ and OUT- terminals.

- **Current reference:** either connect OUT+ to your external positive supply rail and use OUT- as a current source, or connect OUT- to your external ground and use OUT+ as a current sink.
- **Resistance reference:** the resistance shown is available between the IN+ and IN- terminals. OUT+ and OUT- are not used.

Calibration

Automatic calibration primarily involves sensing the value of the resistors in the Programmable Gain Amplifier, used to provide reference voltages above 2.5V. This is not done automatically when the unit is first powered up, as it would complicate testing the unit.

So once the unit is working properly, or if you want to re-calibrate the unit later, simply press the "Menu" button in the lower-right corner, which gives the screen shown in Fig.11. Then press the "Calibration" button, followed by the "Auto. Cal" button.

The relays will click for a few seconds and you should then see new values for the PGA resistors appear, as shown in Fig.12. Press "Back" to exit this screen.

To manually calibrate any value on this screen, simply touch that value (ie, Vref, Rshunt, Rval or one of the PGA resistors) and enter the measured value, or cancel to go back to the calibration screen. You can then use the "Back" button to return to normal operation.

Vref calibration is not necessary and you only need to change Rval if you've used a precision resistor value other than 12kΩ to build the unit.

The one manual calibration you will probably want to perform will be to set a more accurate value for Rshunt. If you've purchased a kit from SILICON CHIP, simply enter the value we supply along with the shunt resistor. Otherwise, you will need a high-precision ohmmeter to measure the shunt value and then enter that.

External voltage reference

The simplest way to use the unit with an external voltage reference is to set it to divider mode and then select the desired output voltage by entering a fraction. For example, say the external reference is 4.096V and you want to get an output of 2.5V. You could achieve this by simply entering an attenuation ratio of "2.5/4.096".

Note that when the unit is used as an unbuffered divider, the IN+, IN-, OUT+ and OUT- terminals are completely isolated from the rest of the circuitry and the maximum applied voltage between IN+ and IN- can range from -60V to +60V. However, when using it as a buffered divider, OUT- is necessarily connected to circuit ground and since normally OUT- and IN- are joined externally, by extension IN- is also. This should not normally matter since the unit's supply will normally be floating but it's worth keeping in mind.

When operated as a resistance reference, the inputs and outputs are also fully isolated, whereas in both voltage reference and current reference mode, OUT- is connected internally to ground.

Other features

When using the unit in current reference mode, the current, voltage and temperature of the controlling Mosfet (Q1) is continuously monitored (or in the case of temperature, estimated) and the temperature is shown on-screen, where the input impedance is normally shown (see Fig.8).

As explained in the October issue, should any of these parameters exceed the normal limits, the output relay will immediately switch off and a message indicating the reason for disconnection will be displayed. You can simply press on this message to dismiss it (see Fig.13) and then switch the output back on again.

When using the unit as a buffered voltage reference or divider, the output will also switch off if the output voltage is pulled outside its normal range by the load, although this would be a rare situation. This is to protect the op amps from being damaged by a backfed voltage and similarly, an on-screen message will appear if this happens to explain why the output has been disconnected.

Pulse test mode

Normally, once the output of the unit has been switched on, it stays on until you switch it off. But there may be situations where you want to feed the output of the unit to its load only for a brief period. This is especially useful if using the unit as a current source or sink above 100mA to prevent it from overheating, for example, while load testing a power supply but it can be applied to any mode.

In this case, you can set an output on-time from 10ms to one minute. You switch the output on manually and it automatically switches off after the set time. Note that the actual on-time may differ slightly from the set time due to relay switching times.

The on-time can be set via the set-up menu, accessed by touching the "Menu" button in the lower right-hand corner. You then have the option to select either continuous (ie, normal) or pulsed operation and set the pulse duration (see Fig.11).

The mode and pulse time are stored in flash memory and will be automatically restored on power-up. When in pulse test mode, a countdown is shown on the screen each time the output is switched on and a message displayed after the output is switched off, which can be dismissed by pressing on it. SC

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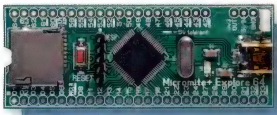

Micromite Plus Advanced Programming, Pt.2

Last month, we went over some of the new features of the Micromite Plus, including reading and writing files on an SD card and defining GUI (graphical user interface) controls. Now we're going to take a look at some extra features which allow even more advanced GUI controls to be built very easily.

By Geoff Graham

AS EXPLAINED in Pt.1 last month, it's trivial to create a GUI control using the Micromite Plus. In most cases, a single line of BASIC will create a check box, text input control or one of nine other different types of GUI elements. The Micromite Plus firmware manages these controls for you, taking care of display and user interaction via the touch interface. The BASIC program can query the state of the controls at a later time, to see what changes the user has made.

Sometimes when a control is touched, you need your program to respond immediately. One way to do this would be with a simple IF statement in the main program loop. For example:

```
IF CTRLVAL(PwrSwitch) = 1 THEN . . .
```

However, with a complex program, it is more efficient to use an interrupt to detect when a control has been touched. This is especially true if the program is performing background processing while the user is interacting with the GUI. To use a touch interrupt, you must first set it up. For example:

```
GUI INTERRUPT IntTouchDown
```

After this command, touching the screen will cause MMBasic to interrupt whatever the main program is doing and execute the code in the subroutine **IntTouchDown**. When this subroutine exits, the main program will continue as if nothing happened (apart from any state changes which occur in that subroutine).

Within the interrupt subroutine, you can discover what control was touched by using the **TOUCH(REF)** function which will return the reference number of the control currently being touched. Note that **REF** is a keyword and should not be replaced with a reference number or variable in this case. In a large program with many controls, it is best to use the **SELECT CASE** statement to select the appropriate code for each control. For example:

```
Sub IntTouchDown
 SELECT CASE TOUCH(REF)
 CASE PwrSwitch
  ' do some action
 CASE OTHERCTRL
  ' do some other action
 END SELECT
END SUB
```

With this sort of structure, you can process almost any touch completely within the interrupt. As a result, the main program could consist of just the commands to set up the controls and then continue with its main job.

Interrupt example code

As an example of how an interrupt could be useful, consider the situation where you would like to run a motor whenever an on-screen switch is touched. This requires the BASIC program to activate the motor's power relay and illuminate a virtual LED on the screen.

First, you need to define two constants. The first is the reference number for the switch control and the second is the reference for the on-screen LED control:

```
CONST PwrSwitch = 41
CONST RedLED = 42
```

Then you would create the controls as follows:

```
GUI SWITCH PwrSwitch, c$, x, y, etc
GUI LED RedLED, c$, x, y, etc
```

Next, the main program should set

up the GUI interrupt and initiate a never-ending loop:

```
GUI INTERRUPT IntTouchDown
DO : LOOP
```

The interrupt subroutine would look something like this:

```
Sub IntTouchDown
 SELECT CASE TOUCH(REF)
  CASE PwrSwitch
   PIN(1) = CTRLVAL(PwrSwitch)
   CTRLVAL(RedLED)=CTRLVAL(PwrSwitch)
 END SELECT
END SUB
```

In the above code fragment, we assume that the motor's relay is connected to pin 1. The **CTRLVAL()** function will get the state of the switch (0 for off and 1 for on) and copy that to pin 1 which will control the relay (ie, "1" means close the relay). We also get that value a second time and apply it to the on-screen LED so that it will reflect the state of the motor.

GUI programming

This concept of handling on-screen activity within an interrupt is common in GUI (graphical user interface) programming but it may be unfamiliar to newcomers.

Conventional programs start by setting everything up, then doing something and then ending. GUI programming is different and this is because it is the user who is in control of the program flow, not the program. The user might touch this control or that; there is no predicting which control will be touched next and a linear program is not the ideal way to handle this.

In a GUI environment, the program should set everything up and wait to see which control the user touches. When the user does touch a control, the appropriate action can be taken and when that action is complete, the program should resume waiting. This can be referred to as an "event-driven program".

The exception is when there is some lengthy processing that must be done as soon as a control is touched. When an interrupt occurs, MMBasic will only run the program in the interrupt subroutine and that means that other interrupts and the main program are blocked. This is fine when the interrupt action is quick (say, less than a millisecond) but if it is lengthy (say, over 100 milliseconds) the effect could be disastrous, as the main loop will freeze while the interrupt is processed.

For example, when a button is touched, you might want your program to send a message to some other item of equipment. Sending a message over a communications link can take some time (eg, half a second) and if that was done within the interrupt routine, it would appear to the user that the program has frozen for this time. Also, if the main loop is performing any real-time tasks, such as monitoring a motor and controlling its speed, the fact that this is not occurring for a significant amount of time could cause real problems.

To avoid this, the interrupt subroutine can set a flag which will let the main program loop know that an action is required. Setting a flag means that the program will write a value into a variable which can then be recognised in another part of the program as a signal to do something. The main loop can then handle that flag in any way it requires. For example, if the flag indicates that a message is to be sent, that message could be sent one character at a time while the main loop continues to run, so that it is not interrupted for a long period.

Here is an example of how you could tackle the above requirement. You first define the flag, then set up the button and the touch-down interrupt:

```
DIM CommFlag = 0
CONST ButtonRef = 42
GUI BUTTON ButtonRef, c$, x, y, etc
GUI INTERRUPT IntTouchDown
```

The interrupt would simply set the flag whenever the button is touched:

```
Sub IntTouchDown
 SELECT CASE TOUCH(REF)
  CASE ButtonRef
   CommFlag = 1
 END SELECT
END SUB
```

The main program loop would then monitor this flag:

```
DO
 IF CommFlag = 1 THEN
  . . . code to send the message . . .
  CommFlag = 0
 ENDIF
LOOP
```

Note that it is the responsibility of the main program to reset the flag so that it then can detect when another message must be sent. If you want the code to avoid blocking the main loop while sending the message, you could increment **CommFlag** as each byte is sent and only reset it to zero at the end.

If doing this, the interrupt subroutine could disable the button (using the **GUI DISABLE** command) until the message has been sent. It could then be re-enabled when the flag is reset, to avoid interrupting a message when transmission has already begun.

Touch-up interrupt

In most cases, you can process all user input in the touch-down interrupt. But there are always exceptions and a typical example is when you need to change the characteristics of the control that is being touched. For example, you might want to change the foreground colour of a button from white to red when it is "down". When it is returned to the "up" state, the colour should revert to white.

Setting the button colour when it is pressed is easy. Just define a touch-down interrupt and change the colour in the interrupt handler routine when that control is touched. However, to return the colour to white when it is released, you need to detect when the touch has been removed from the control (ie, touch-up). This can be done with a touch-up interrupt.

To specify a touch-up interrupt, you add the name of the subroutine for this interrupt to the end of the **GUI INTERRUPT** command. For example:

```
GUI INTERRUPT IntTouchDown, IntTouchUp
```

Within the touch-up subroutine,

Fig.6: the Micromite Plus can drive an LCD panel with up to 800x480 pixels in true (24-bit) colour as demonstrated by this image. It was loaded from the SD card using the LOAD IMAGE command. The speed of loading is not super fast so you would not use this as a photo frame but it is useful for loading logos and background images.

you can use the same structure as in the touch-down subroutine but you need to find the reference number of the last control that was touched. This is because no control is currently being touched. To get the number of the last control touched you need to use the **TOUCH(LASTREF)** function.

The following example shows how you could meet the above requirement and implement both a touch-down and a touch-up interrupt:

```
SUB IntTouchDown
  SELECT CASE TOUCH(REF)
    CASE ButtonRef
      GUI FCOLOUR RGB(RED), ButtonRef
  END SELECT
END SUB

SUB IntTouchUp
  SELECT CASE TOUCH(LASTREF)
    CASE ButtonRef
      GUI FCOLOUR RGB(WHITE), ButtonRef
  END SELECT
END SUB
```

Switching screen pages

Most GUI interfaces will have a number of screens or pages that will be displayed for the user.

For example, there may be a main screen which is first displayed but when the user touches a button labelled "Options", the screen switches to another display which allows the user to set various options.

With the Micromite Plus, this can be easily achieved using the **PAGE** command. For example,

```
PAGE 1
```

will hide all controls currently on the screen and show all the controls associated with page 1. Similarly,

```
PAGE 2
```

will hide all the controls used for page 1 and reveal (un-hide) all the controls associated with page 2.

You can have up to 32 pages, ranging from page 1 to page 32 and you can display two or more pages at the same time. For example,

```
PAGE 1, 5
```

will display both pages 1 and 5. This is useful if you have a set of controls that is common on a number of screens; this set can be defined on one page and that page's number then used in the list for each page switch.

To define which controls are associated with a specific page, you use the following command immediately before the controls are created:

```
GUI SETUP nn
```

where "nn" is the page number that is being set up. In the following example, page 1 has two controls and page 3 has two different controls:

```
GUI SETUP 1
GUI SWITCH 41, c$, x, y, etc
GUI LED 42, c$, x, y, etc

GUI SETUP 3
GUI CHECKBOX 43, c$, x, y, etc
GUI CHECKBOX 43, c$, x, y, etc
```

When a program starts up, the set-up page will default to page 1. This means that if you do not use the **GUI SETUP** command, all GUI elements will be associated with page 1. Also, the page to be displayed will default to page 1 so your program will run perfectly as a single-page application.

Note that the control reference numbers must be unique across all controls, regardless of what page they are on. It is also perfectly legal for the program to change the characteristics of a control on a page which is not displayed. When that page is eventually displayed, the control will be drawn with its new characteristics.

For example, a hidden control might be on a page that's not active. If that page was selected for display, the control will still be hidden when the page is shown. However, the BASIC program can un-hide that control even if the page is not displayed and then, when the page is subsequently selected for display, the control will be visible and active.

Message boxes

One very useful GUI function is **MSGBOX()**. This will display a dialog box in the centre of the screen, with a message and up to four customisable buttons.

When it is invoked, the message box will wait for the user to touch one of the buttons, then return with the number of the button touched. At the same time, MMBasic will redraw any controls that were obscured by the box.

The syntax of the function is as follows:

```
MSGBOX(caption$, b1$, b2$, b3$, b4$)
```

All the arguments are strings and **caption$** is the message to be displayed

YouTube Video

The author has produced a video which describes and demonstrates the capabilities of the Micromite Plus. You'll find it at:

https://youtu.be/j12LidkzG2A

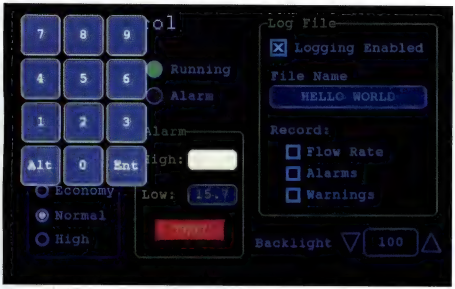

Fig.7: one of the more powerful controls is the NUMBERBOX which is an on-screen box that can hold a number. When it is touched, a number pad will appear, allowing the user to enter any number, including floating point numbers, using scientific notation. Displaying the number pad and entering the number are both done without involving the main BASIC program which can continue with other duties, such as monitoring sensors and other inputs.

in the centre of the box. Multiple lines can be displayed by inserting the "|" (pipe) character into the caption where the new line is to start.

b1$** and **b2$ etc are the captions for the various buttons. The number of buttons displayed is determined by the number of captions specified.

The following is an example of how this function could be used:

```
IF MSGBOX("Start Failed","Cancel","Retry") = 0 THEN
  GOTO EXIT
ELSE
  GOTO RETRY
ENDIF
```

When run, the **MSGBOX** function would display a box containing the words "Start Failed" and two buttons labelled "Cancel" and "Retry". The user will be forced to select either button and when this is done, MMBasic will restore the display to normal and return the number of the button to the BASIC program.

Mixing GUI controls with general graphics

You may be tempted to mix the general graphics commands (**CIRCLE**, **BOX**, etc) with GUI controls but the best advice is simply don't do it.

When you use the GUI controls, MMBasic keeps track of where they are on the screen and their state (ie, visible, hidden, etc) and it will use this information while it is managing the screen. For example, when the user touches a text box, MMBasic will disable all GUI controls on the screen and display them in dull colours. MMBasic will then draw the QWERTY keyboard (to enable user input) over these controls.

The reason that MMBasic disables these controls, by the way, is to indicate to the user that the on-screen keyboard is the only active part of the screen.

On the other hand, MMBasic does not track the location and state of any general graphics commands and they will not be dimmed. Even worse, they may be partially overwritten by the on-screen keyboard and when the user has finished with the keyboard, MMBasic will not redraw them.

You should therefore use either the general graphics commands (**CIRCLE**, **BOX**, etc) or the GUI controls but not both on the same screen display. The one exception is the clear screen command (**CLS**) which will first run through the GUI table and set any visible GUI controls to hidden before it then clears the screen.

If you do want to mix the two types of graphics commands, you should intercept the touch-down and touch-up interrupts for any text box and number box controls. This will indicate that a virtual keyboard has been displayed or removed. During these interrupts, you could then redraw any general graphics that you may have used.

Similarly, you should redraw these graphics immediately after the **MSGBOX()** function has been used, as it will have also overwritten parts of the screen.

Finally, MMBasic for the Micromite Plus will be improved and updated into the future, with new features already planned. To access these updates and other information relating to the Micromite Plus, please check the author's website at **geoffg.net/micromite.html**

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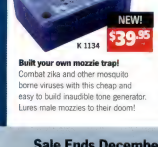

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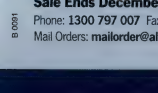

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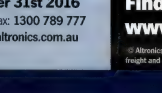

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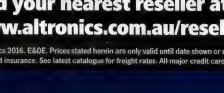

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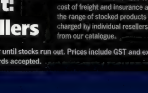

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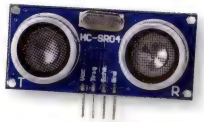
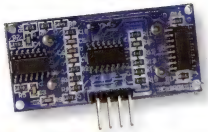




Using Cheap Asian Electronic Modules Part 2

The HC-SR04 Ultrasonic Distance Sensor Module

In the second article on cheap pre-built electronics modules, we're focusing on the HC-SR04 ultrasonic distance sensor module. We describe how the module works and show how it can be used as a hallway monitor or door sentry.

By JIM ROWE

IF THE HC-SR04 module shown in the picture looks familiar, that's because it has already been used in Geoff Graham's Ultrasonic Garage Parking Assistant, published in the March 2016 issue. But this module doesn't have to be used with a microprocessor module like a Micromite or an Arduino, it can also be used with much simpler circuitry, as we'll see later.

Before we get to how it works, we should note these ultrasonic sensor modules have been around for about six years, beginning life as an add-on "shield" for the Arduino. Since then, they have gone through a number of iterations, all bearing the same HC-SR04 label but with various minor circuit and component changes. We suspect this has been due to various manufacturers working out ways of reducing costs, rather than seeking to achieve better performance.

The bottom line is that although some of these slightly different HC-SR04 modules are still being sold, they all seem to function and perform much the same. So don't worry if the module you buy looks a little different from that shown in the photos. The odds are that if your module carries the label HC-SR04, it will work just like any other HC-SR04.

Current HC-SR04 modules are based on a PCB measuring 45 x 20mm. On the top side of the PCB are a pair of small (16mm diameter) ultrasonic transducers with a 4MHz crystal between them.

All the components on the other

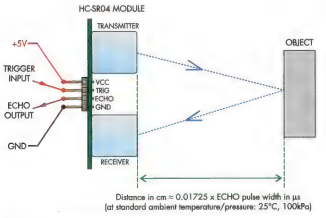


Fig.1: one ultrasonic burst is sent out from the transmitter transducer. The receiver transducer will detect this burst if it is reflected off an object in front of the module. Once detected by the receiver, an output pulse is produced with a width in microseconds of (distance in cm) ÷ 0.01725.

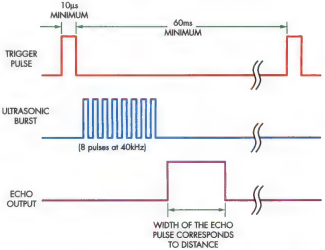


Fig.2: there must be a delay of 60ms between trigger pulses to prevent late echoes from affecting successive readings.

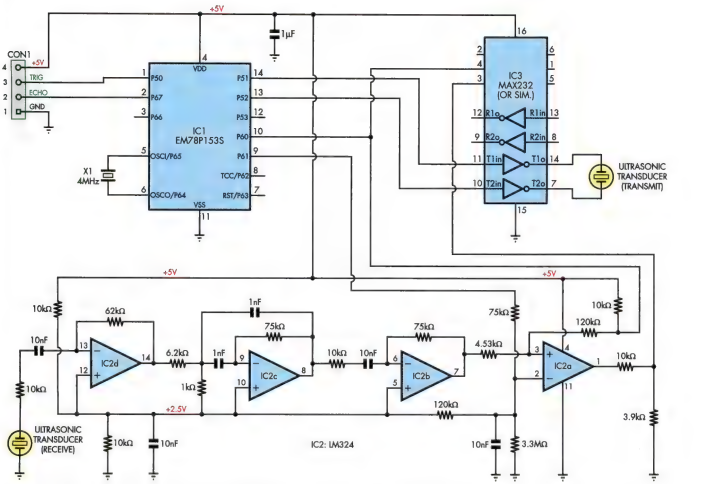


Fig.3: complete circuit diagram for the HC-SR04 ultrasonic sensor module. When IC1 detects a TRIG pulse at pin 1, a 40kHz burst signal of eight pulses is generated at pins 13 and 14 of IC1. This is taken to pins 10 and 11 of IC3 respectively and output at pins 7 and 14 connecting to the transmit transducer.

side of the PCB are surface-mount types, apart from the 4-pin right-angle header at bottom centre. Fig.1 shows how it's used. It sends out a burst of ultrasonic energy from the transmitter transducer (the one marked T, on the left) and then listens via the other receiver transducer (marked R, on the right) for any echo that may be reflected back from an object in front of the module (see Fig.1).

If it detects this ultrasonic echo, it produces an output pulse with a width approximately proportional to the distance between the module's sensors and the object producing the echo.

The ultrasonic frequency used is very close to 40kHz, roughly double the highest frequency that can be heard by human ears. The burst of transmitted energy consists of eight pulses at 40kHz, so the transmitted burst lasts for only 200µs, as shown in Fig.2.

Since the speed of sound in air at 25°C and 100kPa (ie, 1 bar) is close to 345m/s (= 0.0345cm/µs) and the distance travelled by the ultrasonic burst energy corresponds to double the distance between the transducers and the reflecting object, we can calculate the distance from the delay as follows:

$$\text{distance in cm} = \frac{\text{0.0345 x echo pulse width (µs)}}{2}$$
$$= \text{0.01725 x echo pulse width (µs)}$$

As shown in Fig.2, each measurement cycle begins when a positive trigger pulse of at least 10µs duration is applied to the HC-SR04 module's trigger input pin. When the echo has been detected, it then produces a pulse at the echo output pin. Note that there should be at least 60ms between trigger pulses, to prevent late echoes from one cycle from causing false readings on the next. So in practice, it's a good idea to limit the trigger pulse frequency to no more than 16Hz.

Circuit details

The full circuit for the HC-SR04 module is shown in Fig.3. It is based on an EM78P153S microcontroller (IC1), a low power 8-bit CMOS device made by Elan Microelectronics in Hsinchu, Taiwan. This device has a 1024 x 13 bits one-time programmable (OTP) ROM plus 32 bytes of on-chip SRAM, and comes in a 14-pin SOIC package. It runs here with a 4MHz crystal between pins 5 and 6.

When a TRIG pulse arrives at pin 1 of IC1 (from pin 3 of CON1), the controller generates a 40kHz burst signal of eight pulses at pins 13 and 14, with one pin 180° out of phase with the other. These go to pins 10 and 11 of IC3, a bus driver IC very similar to the MAX232. The outputs from IC3 (pins 7 and 14) connect across the transmitter transducer, effectively driving it in bridge mode to emit the bursts of ultrasonic energy.

Echoes picked up by the receive transducer pass through the four sections of IC2, an LM324 quad op amp. These provide amplification, bandpass filtering and phase detection, with the result that a received echo

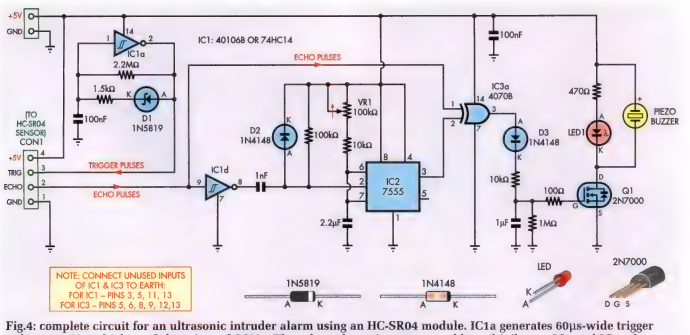


Fig.4: complete circuit for an ultrasonic intruder alarm using an HC-SR04 module. IC1a generates 60µs-wide trigger pulses at 12Hz, which are fed to pin 3 of CON1. The echo pulses trigger monostable multivibrator IC2 and IC3a then compares the width of the resulting pulse to the echo pulse. If these differ, LED1 lights and the piezo buzzer sounds.

pulse is fed back to pin 10 of IC1. The micro then compares the timing of the leading edge of this received echo pulse with the leading edge of the transmitted burst fed to IC3 and the transmit transducer, and produces an echo output pulse at pin 2 with its width equal to the time difference. This echo output pulse appears at pin 2 of CON1.

How it's used

If you want to use the HC-SR04 module to actually measure the distance to an object or wall in front of it, the best way to do it is to hook it up to a microprocessor module like an Arduino, a Micromite or a Raspberry Pi. The micro's program generates the trigger pulse to the HC-SR04, then measures the length of the echo pulse and calculates the corresponding distance.

There's no need to worry about writing a program to do these tasks for you, because many people have already produced programs to do this. A quick search on the Arduino website (**www.arduino.cc**) or by using Google will find a sample program for the micro you're using in short order.

If you want to use the HC-SR04 with a Micromite, Geoff Graham has already built a DISTANCE function into his MMBasic programming language for the Micromite family to make it really easy.

All you have to do to get the Micromite to trigger the HC-SR04 and then calculate the object distance from the echo pulse is use this one-line function call:

d = DISTANCE(trig, echo)

Where "d" is the distance in centimetres, "trig" is the Micromite's I/O pin connected to the HC-SR04's trigger input pin and "echo" is the I/O pin connected to the HC-SR04's echo output pin.

The only extra step is to connect the HC-SR04's +5V and GND pins to the corresponding pins of your Micromite.

If you want to display the result "d" on an alphanumeric LCD, you can do this using commands like:

LCD INIT ...
LCD 1, 2, "Distance = "
LCD 2, 6, STR$(d)
and so on.

You can get a good idea of what's involved in using the HC-SR04 with a Micromite from Geoff Graham's article describing the Ultrasonic Garage Parking Assistant, in the March 2016 issue of SILICON CHIP.

But say you want to use this module without a microcontroller at all. That's fairly straightforward, as we'll now demonstrate.

A simple intruder alarm

For example, to use it as an ultrasonic intruder alarm, have a look at the circuit shown in Fig.4. It uses three low cost CMOS ICs, a 2N7000 Mosfet, three diodes, one LED, a piezo buzzer and some passive components. This circuit and the HC-SR04 operate from a common 5V DC power supply, which can be from a USB plugpack or USB power bank.

IC1 is a hex Schmitt trigger inverter package and we're using just two sections of it, IC1a & IC1b. IC1a at upper left is connected as a relaxation oscillator, to generate a stream of 60µs-wide pulses at a frequency of about 12Hz, ie, with a pulse spacing of about 83ms. These form the trigger pulses which are fed to the HC-SR04 via pin 3 of CON1.

The rest of the circuit monitors the width of the echo pulses sent back from the HC-SR04 via pin 2 of CON1. If this varies significantly (indicating that something has moved between the sensor and the nearest object, like

This tiny active piezo transducer module from Jaycar can be used in the intruder alarm instead of the piezo buzzer.

the opposite wall of your entry hall), it sounds the alarm by switching on LED1 and the piezo buzzer connected across it.

This section is a little more complex. First, the incoming echo pulse passes through inverter IC1d, so that its leading edge is negative-going. The 1nF capacitor and 100kΩ resistor then form a differentiator circuit, which develops a narrow negative-going pulse from the negative-going leading edge of the inverted pulse.

This is then used to trigger IC2, a 7555 CMOS timer chip connected as a one-shot multivibrator. When IC2 is triggered, its output pin 3 switches high for a short time, determined by the 2.2µF capacitor connected from pins 6 and 7 to ground and the resistance connected between the same two pins and the +5V line.

As shown, this resistance is the series combination of a 10kΩ resistor and VR1, a 100kΩ pot. So by varying VR1, we can vary the width of the pulse generated each time the one-shot is triggered.

The output of IC2 is connected to pin 2 of IC3a, one section of a 4070B quad XOR (exclusive-OR) gate. The echo pulses from the HC-SR04 are fed to pin 1 of IC3, the second input of the same XOR gate. Since the output of an XOR gate is high only when one of its inputs is high and the other low, it forms a pulse width comparator.

Consider the situation where the HC-SR04 sensor is facing a wall say 1.5m or 150cm away. The echo pulses fed back from the sensor will be very close to 8.7ms wide and these are fed to input pin 1 of IC3a.

If we adjust VR1 so that IC2 also produces 8.7ms wide pulses, since they start at virtually the same instant as the start of the echo pulse, both inputs of XOR gate IC3a will rise and fall at the same time. As a result, the output of IC3a (pin 3) will remain low at all times.

But if someone moves in front of the HC-SR04, this will cause the echo pulses to shorten, because the ultrasonic energy reflected back by the person or object will be travelling over a smaller distance. So the echo pulse width will drop briefly to say 5-6ms, and as a result the inputs of IC3a will no longer be synchronised.

Although the pulses fed to pin 2 will still be high for 8.7ms, the echo pulses being fed to pin 1 will drop low after 5-6ms, so the output of IC3a will switch high for the remaining 2.7-3.7ms. These positive-going pulses will very quickly charge up the 1µF capacitor in the gate circuit of Mosfet Q1, via diode D3 and the 10kΩ series resistor, and this will turn on Q1, causing LED1 to light and the piezo buzzer to sound the alarm.

Then when the intruding person or object moves away again and the echo pulses return to their original width of 8.7ms, the pulses fed to the two inputs of IC3a will be again be synchronised. There will be no more output pulses from IC3a and the 1µF capacitor will be discharged by the 1MΩ resistor connected across it. So within a couple of seconds, the buzzer and LED will switch off.

The circuit is quite easy to set up, too. All you need to do is wire it up and connect it to the HC-SR04 module using a suitable length of 4-conductor cable. Then mount the sensor module on one side of the hall or doorway to want to monitor, facing either a wall or a large fixed object such as a dresser, a chest of drawers or a filing cabinet.

Next, set pot VR1 to its fully anticlockwise (ie, minimum resistance) position and turn on the 5V power supply. You'll find that LED1 will immediately light, and if you have a piezo buzzer connected as well, it will sound. That's because the pulses being generated by the one-shot IC2 will be shorter than the echo pulses coming from the HC-SR04.

Now slowly turn pot VR1 clockwise until LED1 turns off and the piezo buzzer goes silent. Your intruder alarm will then be set up and ready to detect the presence of a "foreign body" in the space between the sensor and its reflecting wall. So we've done all this without a microprocessor – apart from the EM78P153S micro inside the HC-SR04 sensor module itself, of course. SC

Parts List

1 HC-SR04 ultrasonic sensor (Jaycar XC4442)
1 active piezo transducer module (Jaycar XC4424) ***OR***
1 piezo buzzer
1 100kΩ trimpot (VR1)

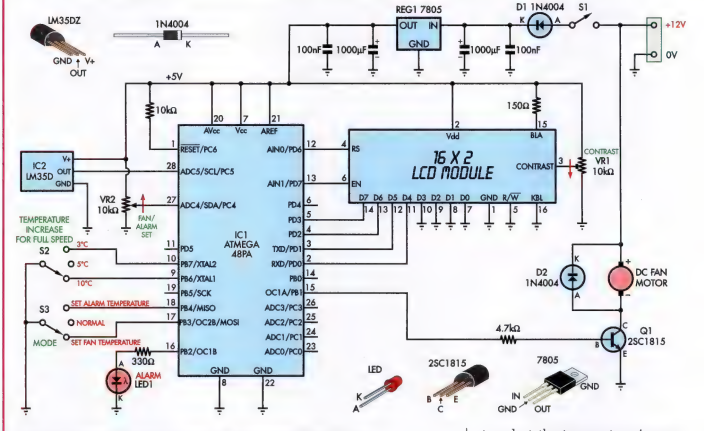
Semiconductors
1 1N5819 diode (D1)
2 1N4148 diodes (D2)
1 LED, any colour (LED1)
1 2N7000 mosfet (Q1)
1 40106B or 74HC14 CMOS IC (IC1)
1 LM7555 CMOS timer IC (IC2)
1 4070B quad XOR gate IC (IC3)

Capacitors (16V)
1 2.2µF
1 1µF
2 100nF
1 1nF

Resistors (0.25W, 5%)
1 2.2MΩ, 1 1MΩ, 1 100kΩ
2 10kΩ, 1 1.5kΩ, 1 470Ω
1 100Ω

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



PWM-based temperature-controlled fan

This circuit controls the speed of a DC fan, depending on the output of a temperature sensor, and it can switch the fan on and off and adjust its speed in steps as the temperature increases. The number of degrees increase required to run the fan at full speed is selectable at either 3°C, 5°C or 10°C. It can also sound an over-temperature alarm if the temperature rises above a critical value.

Potentiometer VR2, switch S3 and a 16x2 alphanumeric LCD are used to set the fan-on temperature and alarm temperature. During normal operation, this LCD shows the current temperature, fan cut-in temperature, alarm temperature and current fan speed.

The circuit uses an LM35 precision temperature sensor, IC2, which gives an output of 0V + 10mV/°C, ie, its output is 1V at 100°C. This voltage is fed to the ADC5 analog input (pin 28) of IC1, an ATmega8 microcontroller. Another analog input, ADC4 at pin 27, monitors the voltage at the wiper of potentiometer VR2.

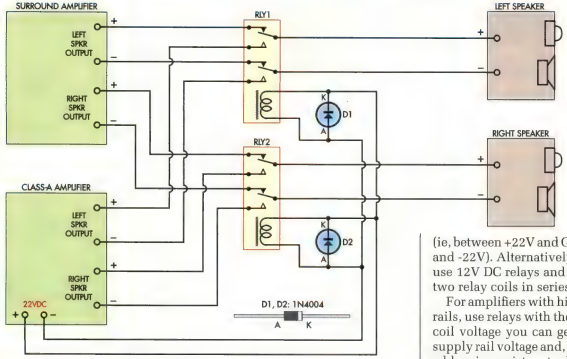
Once the micro has measured the temperature, it decides what speed the fan needs to run at and produces an appropriate PWM signal from its OC1A output at pin 15. This drives the base of NPN transistor Q1 via a 4.7kΩ base current-limiting resistor and Q1 in turn switches pulses of current through the 12V DC fan. The higher the PWM duty cycle, the faster the fan runs.

The PWM output at pin 16 (OC1B) generates a separate PWM signal to drive alarm LED1 via a 330Ω current-limiting resistor. This LED is on when the unit is first powered up but fades out after a few seconds or flashes at full brightness in an over-temperature alarm condition.

Three-position switch S2 is used to select the temperature increase required for full fan speed. IC1 has individually-enabled internal pull-up current sources for each pin and the software switches these on for input pins 9 & 10. Hence, it can determine the position of S2 by reading the voltage at these inputs, as one or the other is pulled low (or neither), depending on the position of S2.

Note that the fan will continue to run for 60 seconds once the sensed temperature drops below the set threshold. During this time, a count-down is shown in the upper-right corner of the LCD screen. The fan then switches off. This prevents the fan from switching on and off if the temperature is hovering near the set-point.

IC1 reads the position of switch S3 via input pins 17 & 18 in the same manner as it monitors S2. S3 is used to set the fan-on temperature threshold and the alarm temperature threshold. During normal operation,



Automatic speaker switching between two power amplifiers

This simple circuit shows how two 24V DC coil high-current DPDT relays can be used to switch one pair of speakers between two amplifiers. In this case, the speakers are shared between a SILICON CHIP 20W Class-A amplifier (May-August 2007), for music, and a surround sound amplifier, for watching TV and movies.

When the Class-A amplifier is switched on, its 22V DC supply rail is used to energise the two relay coils and the relays connect the speaker + and – terminals to the outputs of that amplifier. When this amplifier is switched off, the coils are de-energised and the speakers are instead connected to the + and – outputs of the surround-sound amplifier.

Both terminals are switched so that this arrangement will work properly even if the surround-sound amplifier drives the speakers in bridge mode. In this case, both the negative and positive terminals are actively driven; if relays were used to only switch the positive outputs, with the negative outputs connected to Earth permanently via the Class-A amplifier negative outputs, this could prevent the surround sound amplifier from operating properly and possibly even damage it.

The Class-A amplifier has ~22V DC supply rails, so if the relay coils are connected in parallel, they can be powered directly from either of the two amplifier supply rails directly (ie, between +22V and GND, or GND and -22V). Alternatively, you could use 12V DC relays and connect the two relay coils in series.

For amplifiers with higher voltage rails, use relays with the highest DC coil voltage you can get below the supply rail voltage and, if necessary, add series resistors to drop the coil voltage to within the relay's operating range.

To determine the resistor value required, multiply the relay coil resistance by the difference between the supply and coil voltages, then divide by the coil voltage. For example, to run a 24V relay with a coil resistance of 1kΩ from a 35V supply rail, use a (35V - 24V) x 1000Ω ÷ 24V = 458Ω series resistor; 470Ω is the closest value available.

To determine the required resistor power rating, square the difference in voltages and then divide by the resistor value. So in this case, (35V - 24V)^2 ÷ 470Ω = 0.257W so a half-watt (or higher) rated resistor is suitable. Add one such resistor in series with each relay coil.

Peter Clarke,
Woodcroft, SA. ($40)

S3 is left in the middle position. To set either threshold, it is switched to one of the other positions and then VR2 is rotated until the desired value (in °C) is shown on the LCD. S3 can then be set back to its centre position and the new setting is stored in IC1's EEPROM.

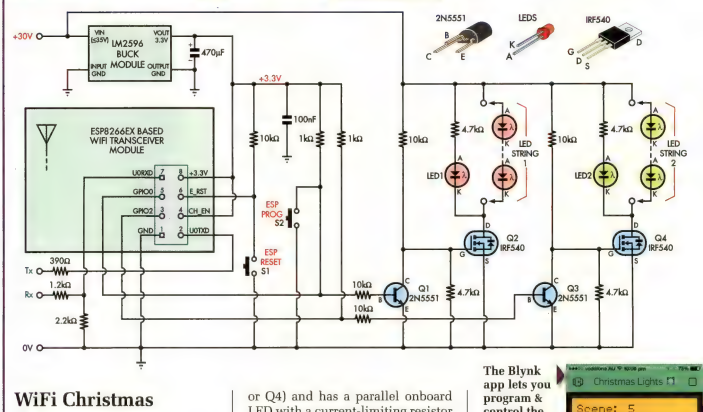
The LCD interface uses the standard 4-bit configuration, with output pins PD0-PD3 (pins 2-5) used to send data and outputs PD7 (pin 13) and PD6 (pin 12) for control. The LCD backlight is powered via a 150Ω current-limiting resistor from the 5V rail while the contrast is set using 10kΩ potentiometer VR1.

On the LCD, the current temperature is shown after "T:", the alarm temperature threshold after "A:", fan temperature threshold after "F:" and current fan speed step after "Sp:". It also shows a blinking heart symbol as a "heartbeat" at 1Hz to indicate that the unit is operating.

Power comes from a 12V supply via power switch S1, reverse polarity protection diode D1 and 5V linear regulator REG1 which has a pair of input bypass capacitors and two output filter capacitors. Before switching the unit on for the first time, VR2 should be rotated fully clockwise and S3 set to the SET FAN TEMPERATURE position.

The software is written in BASIC and can be compiled into a HEX file to load into the Atmel processor using BASCOM. The source code is available for download from the SILICON CHIP website (*Software-pwm-based temperature-controlled fan.bas*).

Mahmood Alimohammadi,
Tehran, Iran. ($60)



WiFi Christmas light controller

This Christmas light controller is based on a small, low-cost ESP8266 WiFi/microcontroller module and drives two strings of LEDs. Multiple controllers can be built and used to provide synchronised light shows, controlled from an Android smartphone or iPhone.

The ESP8266 module runs off 3.3V and has a WiFi interface, two general-purpose I/O lines and a serial port. This is controlled from an app called Blynk which allows custom user interfaces to be built on Android or iPhones. Blynk is specifically designed to interface with Arduino, Raspberry Pi or ESP8266 modules.

The supplied software provides 11 different light patterns or "scenes". The Blynk interface allows one of these scenes to be selected and other aspects to be controlled, including the flash rate and the time to display one scene before moving on to the next in an endless loop.

The circuit is designed to utilise typical LED lighting strings which commonly have two strings of LEDs, with a common anode, that operate at about 30V. Each string is switched by an IRF540 N-channel Mosfet (Q2 or Q4) and has a parallel onboard LED with a current-limiting resistor for debugging purposes.

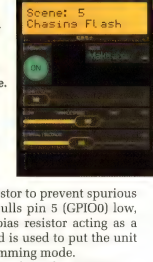
The gates of Mosfets Q2 and Q4 are biased to around +10V by 10kΩ/4.7kΩ divider resistors across the 30V supply. They are switched off by NPN transistors Q1 and Q3 which pull the gates down to 0V when switched on and allow the gates to rise to 10V when switched off, which results in current flowing through the LED strings. These transistors, in turn, are driven from outputs GPIO0 (pin 5) and GPIO2 (pin 3) of the ESP8266 module, with 10kΩ base current-limiting resistors and 1kΩ pull-ups from the 3.3V supply rail, so that Q1 and Q3 are on by default and thus Q2 and Q4 are normally off.

The ESP8266's serial port is on pins 7 (receive) and 2 (transmit) and this is brought out to a separate 3-pin header for external use. The transmit pin has a 390Ω series current-limiting resistor for ESD and short-circuit protection, while the receive pin is fed via a 1.2kΩ/2.2kΩ voltage divider, allowing it to be safely driven with a 5V TTL signal.

There are two pushbuttons. S1 resets the ESP8266 by pulling pin 6 to ground and is equipped with a 10kΩ pull-up resistor to prevent spurious resets. S2 pulls pin 5 (GPIO0) low, with Q1's bias resistor acting as a pull-up, and is used to put the unit into programming mode.

The 3.3V rail for the ESP8266 is derived from the 30V DC LED supply by an LM2596-based step-down module which accepts an input of up to 35V and provides a regulated 3.3V output. It is fitted with 100nF and 470µF filter capacitors on its 3.3V output.

Before programming the ESP8266, you must first alter the software. Before that, though, add the ESP8266 libraries to the Arduino IDE and select the generic ESP module as the target board, using the Tools menu. Details on how to do this can be found at https://github.com/esp8266/Arduino



The Blynk app lets you program & control the LED display using an iPhone or an Android smart-phone.

Then you can download the sketch (*ESP8266_Blynk_Christmas_Lights.ino*) from the SILICON CHIP website and open it in the Arduino IDE.

To enable secure communication between the software and the hardware, a Blynk authorisation code is required. The code is provided when a new project is created in the Blynk App. The code can be emailed and then pasted into the Arduino sketch. Your WiFi network SSID and security code must also be entered into the sketch to enable the WiFi connection.

Next, you will need to configure the Blynk app. Refer to the adjacent table to see which controls and options you will need to set.

Once you have Blynk set up, connect a USB/5V TTL serial adaptor to your PC and the serial port on the Christmas light controller and set it up (in the Arduino IDE) for a baud rate of 76,800 (which is what the ESP8266 defaults to). Now hold down S1 and S2 simultaneously, then release S1 and while still holding S2, initiate the upload from the Arduino IDE (CTRL+U). You can release S2 once the IDE indicates that it has finished compiling the code and begun uploading it.

Blynk Widget Settings

Widget	Mode	Input/Output pin	Label/Text/Items
LCD	Simple	(0) Virtual Pin V21 line 1 (1) Virtual Pin V22 line 2	
Pushbutton	Switch	Virtual pin V4	Combination
Menu (Hint: make a selection		Virtual pin V1	Scene 1 - All on 2 - In waves 3 - Sequential 4 - Slow glow 5 - Chasing flash 6 - Slow fade 7 - Twinkle flash 8 - Twinkle 9 - Varying twinkle 10 - Flicker 11 - Flicker alternating 12 - All off
Slider	Send values on release – On	Virtual pin V0 Values 1 to 12	Scene (1 to 12)
Slider	Send values on release – On	Virtual pin V2 Values 750 to 0	Slow-Twinkle Speed-Fast
Slider	Send values on release – On	Virtual pin V3 Values 5 to 60	Interval (seconds)

Note that if you don't have a 5V TTL serial adaptor, you can use a 3.3V adaptor and omit the resistive divider on the receive pin. Also, you can edit the sketch to add more scenes to the 11 supplied, if desired. Note that the analogWrite(pin,value) function is used throughout the sketch to control the GPIO ports as this provides PWM of the outputs for dimming the LEDs.

The unit is powered from a 30V supply rated to deliver at least 500mA.

Phillip Webb,
Hope Valley, SA. ($80)

Level shifter/inverter for back-EMF sensing

Because N-channel Mosfets and NPN transistors generally have better performance compared to equivalent P-channel Mosfets and PNP transistors, it's tempting to control motor speed by connecting the motor positive terminal permanently to the positive supply and then switching the negative terminal to ground. This can also simplify the control circuitry, as it will normally have its ground rail connected to the power supply negative rail.

However there's a disadvantage to this approach: if you want to sense the motor's back-EMF for speed regulation, when the transistor switch is off, the negative terminal of the motor tends to sit near the positive supply rail and back-EMF causes a reduction in this voltage. This makes sensing the back-EMF tricky, especially if there's a lot of supply noise or ripple overlaid on it.

You can easily use an op amp configured as a differential amplifier to invert the back-EMF signal and shift it to be relative to the negative rail, so it can be filtered and fed to an analog-to-digital converter or analog circuit, for speed regulation. However, typical op amps will only operate to about 40V. So if you're dealing with a 48V (or higher voltage) motor, you would need an expensive and difficult-to-get high-voltage op amp, or a tricky supply arrangement.

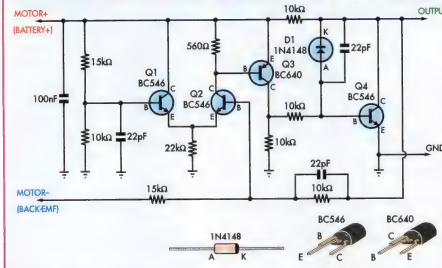
This circuit provides an alternative. It uses just four transistors and a handful of passive components to invert and level-shift the back-EMF signal, giving you a positive-going, ground-referred output. While its accuracy and performance are compromised somewhat by its simplicity, it's more than adequate for speed regulation feedback. In this form, it will operate with a motor supply of up to 80V and switching speeds of at least several kilohertz.

It works as follows. NPN transistors Q1 and Q2 form a differential pair, with the base of Q1 acting as

continued next page

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au



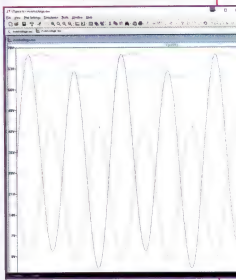


Fig.1: a simulation of the circuit. The motor+ terminal voltage is the green trace, the motor- terminal is the blue trace and the output voltage is the red trace.

Level shifter/inverter for back-EMF sensing – continued

the non-inverting input and the base of Q2, the inverting input. The non-inverting input is connected to a voltage divider across the motor supply, with a 22pF capacitor to reduce the effect of high-frequency hash. The inverting input is connected to a similar divider between the circuit's output and the motor's negative terminal, which serves as the motor back-EMF signal source when the motor is not being driven (ie, when the low-side switch transistor(s) are off).

The difference in voltage between the two inputs changes the current through Q2's 560Ω collector resistor and the resultant voltage controls PNP transistor Q3. Its base current is amplified and converted into a voltage relative to the negative rail (ground) by its 10kΩ collector resistor. The voltage across this resistor then controls NPN transistor Q4, which acts as an inverter, in combination with another 10kΩ collector pull-up resistor.

A 22pF capacitor between Q4's base and collector reduces the bandwidth of the circuit to around 20kHz, to prevent oscillation, while diode D1 stops this capacitor from charging to more than about -0.5V at times when the output is near 0V, which greatly improves recovery from this condition and also improves stability.

To better understand how the circuit works, consider what happens if the motor's negative terminal starts at a voltage similar to its positive terminal and then drops. Assume that the circuit output is initially 0V. In this condition, the bases of both Q1 and Q2 are initially at 40% of the supply voltage but the voltage at the base of Q2 then begins to drop.

This reduces the current through Q2's collector and hence the voltage across its collector resistor, increasing the voltage at Q3's base. This reduces Q3's base bias, thus reducing the current flowing to the base of Q4. This in turn causes it to start to switch off, allowing the output voltage to rise, so the feedback voltage at the base of Q2 starts to rise. This cancels out the drop in that voltage due to the lower back-EMF voltage.

Hence, the bases of Q1 and Q2 are held at essentially the same voltage, with the output voltage rising when the back-EMF voltage falls and vice versa.

The overall gain is set to around 67% because the output at Q4's collector can't swing all the way up to the positive rail. Normally, the back-EMF signal needs to be attenuated to be sensed anyway, so you can simply compensate by reducing the attenuation ratio. The ratios of the pairs of 10kΩ and 15kΩ resistors can be changed to adjust the overall gain of the circuit; for unity gain, use identical value resistors (eg, change the two 15kΩ resistors to 10kΩ). For lower gain, increase the value of the 15kΩ resistors.

Fig.1 shows a simulation of this circuit, with the motor + terminal voltage shown in green (with 10kHz ripple), the negative terminal varying in a 20kHz sinewave at greater than the full supply amplitude (blue waveform) and the output voltage in red.

Nicholas Vinen, SILICON CHIP.

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Vintage Radio

By Ian Batty

Shown at right in the above photo, Grundig's 1958 Taschen-Transistor-Boy was much larger than Regency's shirt-pocket size TR1 receiver (left).

Grundig's 1958 Taschen-Transistor-Boy 58

Large Shirt-Pocket Required

Sized to fit in a coat pocket rather than a shirt pocket, Grundig's Taschen-Transistor-Boy is a well-engineered 6-transistor set with some interesting design features. It's a design that emphasised quality rather than miniaturisation.

I WAS OFFERED this set by a fellow HRSA member for a "look-over". He'd bought it at a swap meet some years ago and he wondered why I'd never described any early European sets – only my early US, English, Japanese and Australian radios.

Well, this review of Grundig's 1958 Taschen-Transistor-Boy makes up for that omission.

Some history

German company Furth, Grundig & Wurzer first began selling radios in 1930. Immediately following World War 2, Max Grundig recognised the need for radios in Germany and began with a radio kit. During this time, the company built a factory and administration centre at Furth and by 1951, Grundig had become the largest radio manufacturer in Europe and had begun producing TV sets.

That the company had literally risen from the devastation of war to become Europe's largest radio manufacturer in a scant six years was a tribute to its entrepreneurship and engineering talent.

A "pocket" set?

"Taschen" translates from German as "pocket" but in this case, maybe it's meant to be a "coat pocket" set. That's because it's hard to imagine any shirt pocket being large enough to carry this fine portable radio.

Grundig's Taschen-Transistor-Boy is physically larger than many similar sets of the late 1950s, so it's interesting to consider its physical design. Grundig's own website gives the year of its introduction as 1958 but a photo on the Radio Museum website dates it to 1957.

The set uses four AA-size cells for its 6V power supply. With roughly twice the volume of the Regency TR-1's 22.5V battery or the more usual PP9 used in Sony's TR-63, the battery pack is just one factor contributing to the set's comparatively large size.

By contrast, the tuning gang is a small air-spaced type similar to that of the TR-1. However, the tuning dial, rather than being direct-drive as in other sets, uses a simple gear-train between the tuning knob and the gang. Add in the fact that this is a design aimed at quality rather than miniaturisation and you have a set with a volume of some 590cc compared to the TR-1's more compact 295cc.

Basically, Grundig's Taschen-Transistor-Boy is a well-engineered, 6-transistor superhet. It uses the Philips OC44 & OC45 (x2) transistors in its RF/IF section and OC71 & OC72 (x2) transistors in the audio stages. Two

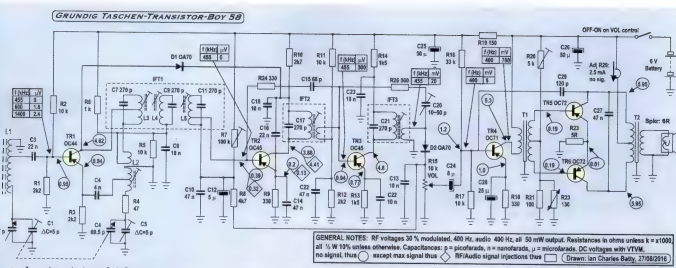


Fig.1: the circuit is a fairly conventional 6-transistor superhet design. Transistor TR1 is the converter stage, TR2 and TR3 are IF amplifier stages and D2 is the detector. TR4 functions as an audio driver stage and this feeds a push-pull output stage based on TR5 & TR6 via phase-splitter transformer T1.

OA70 diodes (demodulator and AGC extension) complete the semiconductor line-up.

Circuit description

Fig.1 shows the circuit details. At first glance, it's a pretty conventional 6-transistor superhet but a second look soon reveals some interesting features.

Converter stage TR1, an OC44, operates with collector-emitter feedback. As noted in other articles, this gives less local oscillator radiation than does base injection feedback. It also allows the circuit to operate in grounded-base configuration to give more reliable oscillation across the entire broadcast band.

Although designated on the circuit as IFT1, the usual first IF transformer actually consists of a filter section based on coils L3, L4 & L5, all contained within one elongated metal can with three slugs (see photo). L3 looks pretty much like the usual first IFT primary, with a slug-tuned winding tapped off for the converter's collector (TR1). This tapping allows the circuit to achieve maximum Q factor by reducing the loading due to the converter's moderate output impedance.

Inductor L4 is magnetically-coupled to L3 and has a single tuned winding. This in turn is magnetically coupled to L5, with the latter's tapped winding feeding the first IF amplifier stage which is based on transistor TR2 (OC45).

It's an unusual circuit for a transistor set, although anyone who has worked on high-performance radio circuits will recognise the L3-L5 circuit as a bandpass filter. In fact, it's correct to think of any IF channel as a bandpass filter, since it's designed to pass only a narrow band of frequencies centred on the IF.

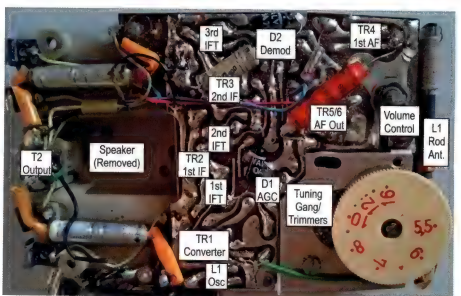
The IF signal from L5 is fed to TR2's base. This is configured as a common emitter amplifier and its gain is controlled by the AGC voltage derived from the demodulator.

Potentiometer R7 allows TR2's bias to be adjusted. This is the first time I've seen this arrangement in this type of set, with other circuits simply using a fixed high-value fixed resistor (33kΩ plus) in this position.

Because it's an OC45, TR2 needs to be compensated for its high collector-base capacitance. This circuit uses the preferred RC feedback arrangement (R24-C15) to provide what's known as "unilateralisation". This is similar to neutralisation and is necessary to ensure stability of the first IF amplifier stage.

TR2's collector feeds the primary of IFT2, the second IF transformer. It's here that things again vary from usual practice.

As shown, IFT2's primary is tuned but untapped. Its low-impedance, untuned secondary feeds signal to the base of TR3 (OC45), the second IF amplifier stage. Unlike L3-L5, IFT2 is wound on a toroidal ferrite core. It



The copper side of the PCB carries AGC diode D1 and just a few other parts. The relatively large tuning gang occupies a cut-out in the PCB at bottom right and is directly tuned by a small thumbwheel control

The styling is quite plain with just two thumbwheel controls, one for volume (left) and the other for tuning. Despite its age, the set cleaned up quite nicely.

can be seen in one of the photos, immediately above bandpass filter IFT1's metal can.

IFT2's tuning capacitor (designated C17) is mounted within the ferrite core. It's a wire trimmer of the type more usually seen in aerial and oscillator tuned circuits.

TR3 (the second IF amplifier) operates as a common-emitter stage with fixed bias. Its collector feeds IFT3 which is another toroidal transformer, this time tuned by C21. However, whereas TR2 has fixed unilateralisation, TR3's input capacitance is compensated for using adjustable trimmer C20 which is in series with R26.

The untapped primary windings of IFT2 and IFT3 are loaded by the moderate output impedances (around 30kΩ) of their respective IF amplifiers. This implies that their selectivity won't be especially high.

So does the L3-L5 combination set the IF selectivity (ie, the bandpass), with IFT2 and IFT3 having a much wider response? Theory says it should but we'll find out in the "How Good Is It?" section below.

IFT3's secondary feeds demodulator diode D2, an OA70. As usual, this diode is weakly forward biased, in this case via TR2's adjustable bias pot R7. It demodulates the IF signal and supplies a positive-going AGC voltage to TR2 (via R8 and L5) to control its gain on strong signals.

There's also D1, another OA70. As shown on Fig.1, its cathode connects from the DC supply of the first IF amplifier (TR2), while its anode goes to the "hot" end of L3 in IFT1.

Divider resistors R6 & R5 set converter TR1's collector voltage to about 4.6V. With no signal (and thus no AGC applied), TR2's collector voltage is around 3.9V, so D1 is reverse-biased in the absence of AGC action. However, once the AGC takes effect, TR2's collector current drops, allowing its collector voltage to rise.

Once this approaches 4.6V, D1 starts to conduct and partially shunts the IF signal at its anode (the converter's collector) to signal ground. It's the standard "AGC extension" diode seen in many Philips/Mullard-influenced designs.

As for that adjustable capacitor in the second IF amplifier's feedback circuit, I did try adjusting it and found that I could either reduce the gain or cause the set to go into oscillation. It worked just as expected and in the end, I simply reset it to its original position.

Audio stages

Despite the somewhat unusual circuitry in the RF and IF sections, it's all fairly straightforward after the volume control.

The audio signal from the demodulator (D2) is filtered and fed to transistor TR4 via volume control R15 and capacitor C24. TR4, an OC71, functions as an audio preamplifier. Its output feeds driver transformer T1 which functions as a phase splitter.

T1's tapped secondary matches the low input impedances of output transistors TR5 & TR6 which operate as a class-B push-pull output stage. Their bias current is set by divider resistors R20, R21 & R23. Resistor R20 allows the output stage's quiescent current to be adjusted and this is set to just 2.5mA.

R22 is a negative temperature coefficient (NTC) thermistor which responds to ambient temperature. It reduces output stage bias at higher temperatures and thus prevents excessive collector current.

Capacitor C27 (across the output transformer's primary) cuts the high-end frequency response, while feedback capacitor C29 between TR5's collector and TR4's base reduces the distortion at upper audio frequencies.

Service data

The original service sheets give circuit voltages and adjustment data for trimmer resistors R7 (0.16V at TR2's emitter) and R20 (2.5mA total quiescent current). Grundig specify a battery voltage of 5V for testing but I've used 6V for all measurements (see below). During testing, I discovered that a 5V supply gives a sensitivity reduction of some 30%.

Grundig's service sheets also show the parts layout on the PCB and give alignment and performance details. The sensitivity is specified as

Grundig's Path To An All-Transistor Radio

Grundig's Taschen-Transistor-Boy is especially impressive given that it uses just six Philips alloyed-junction transistors. We're so familiar with both the OC44/45 and OC70/71/72 transistor series that we no longer appreciate the prodigious effort needed to make them available to manufacturers and hobbyists during the late 1950s.

Philips had originally considered Bell Labs' grown-junction technology but after finding them difficult to manufacture and suitable only for audio applications at that stage, eventually decided on the alloyed-junction technology developed by Pankove and Saby.

Philips' first practical device, the TA-153, appeared in 1953, followed by the OC10/11/12 series. Suitable only for "circuit experiments", they quickly became obsolete and were replaced by the OC70/71 in 1954 and the OC72 in 1955.

Several European manufacturers (including Grundig) subsequently released hybrid portable radios in the mid-1950s that used miniature 1.4V valves in the RF/IF section and transistors in the audio section. However, fully-transistorised radios had to wait for the OC44/45 series which first appeared in 1956. Grundig then finally released this all-transistor set in 1957.

Quiescent Current Adjustment

Exercise caution if you need to adjust the output stage's quiescent current. Bias pot R20 is the only component that limits the output stage bias, since there's no fixed series resistor. As a result, careless adjustment of R20 could easily result in excessive (and destructive) collector current through the output stage.

100~300μV, while the maximum audio output is specified as 80mW.

Cleaning up

While it lacks the arresting visual design of Regency's TR-1 or Philco's T7, this set is still attractive to look at. Like the Philips 198, its European design ensures that its appearance is modest and unassuming. Ernst Erb's Radio Museum website has photos of a red example and it's well worth a look.

This particular set was a bit grubby as it came to me but cleaning it with spray detergent and then applying car polish brought it up nicely. Removing some battery contact corrosion and spraying the volume pot with contact cleaner got the set functioning.

Distortion

Unfortunately, the audio distortion was initially quite noticeable, both audibly and on an oscilloscope. It measured some 15% at all volume levels and the scope indicated much more gain on one half-cycle, with clipping beginning to occur at just 40mW.

Replacing one of the output transistors fixed the audio output waveform and increased the maximum power output.

One interesting feature is that the set is fitted with transistor sockets and these make it relatively easy to replace the transistors. Be careful when doing this though; I found that the transistors were extremely hard to remove and reinsert and it's all too easy to badly bend the leads.

There's a small crack in the back of the case but I'll leave that for the owner to consider repairing.

How good is it?

So just how good it? Well, for a set first offered in 1957, just three years after Regency's TR-1, it offers great performance. It's one of those sets where it's hard to find a spot on the dial with no station coming in.

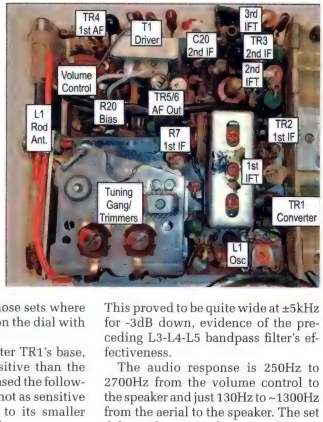
If we start at converter TR1's base, it's actually more sensitive than the Philips model 198 released the following year. However, it's not as sensitive overall, probably due to its smaller "pocket set" ferrite rod antenna.

The measured sensitivity (for 50mW output) is 70μV/m at 600kHz and 100μV/m at 1400kHz, while the corresponding signal-to-noise (S/N) ratios are 13dB and 16dB respectively. A 20dB S/N ratio requires signal strengths of 110μV/m at 600kHz and 120μV/m at 1400kHz.

The set's IF bandwidth came in at ±1.4kHz at the -3dB points and 14kHz at -60dB. Its AGC response is outstanding; increasing the signal strength from 150μV/m to 50mV/m (ie, by around 50dB) results in an audio output increase of just +5dB. It ultimately goes into overload at around 125mV/m.

What about the IF bandwidth from the first IF amplifier (TR2) onwards?

The component side of the PCB is closely packed, although access to individual parts is quite good. Replacing one of the output transistors restored the set to full working condition. Note that the "1st IFT" actually consists of a filter section based on L3, L4 & L5 (see Fig.1).



This proved to be quite wide at ±5kHz for -3dB down, evidence of the preceding L3-L4-L5 bandpass filter's effectiveness.

The audio response is 250Hz to 2700Hz from the volume control to the speaker and just 130Hz to ~1300Hz from the aerial to the speaker. The set delivered its quoted output of 80mW at clipping with 9% THD, while at 50mW, the distortion was just 2.3%. This increased slightly to 2.7% for an audio output of 10mW.

Reducing the power supply to just 3V resulted in the set clipping at 20mW output. This also noticeably increased the crossover distortion, with 5% THD at just 10mW output.

Would I buy one?

Would I go so far as to buy one of these sets. Yes, certainly; it's a very good performer and is technically interesting to boot. It really is a fine example of early European transistor radios. SC

Other Versions?

Ernst Erb's Radio Museum website at **http://www.radiomuseum.org/r/grundig_taschen_transistor_boy.html** shows a very nice red example of this set, while the Audio Engineering Society website has a stunning purple one (you'll need to scroll down to find it on the page) – see **http://www.aes.org/aeshc/docs/recording.technology.history/tape5.html**

The follow-on 1959 model uses the same case but has a more conventional IF strip. It also has fixed neutralisation for the second IF amplifier.

Ernst Erb's Radio Museum site also has information on earlier, hybrid, "Transistor-Boy" models and it's interesting to compare the various designs. For example, the model 57E uses four miniature valves followed by a push-pull transistor output stage. It also features a single-transistor DC-DC converter to derive an HT supply (for the valves) from the 6V battery.

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LM1084IT-ADJ, KCS5603D, 3 x STX0560, 5 x blue 3mm LEDs, 5 x 39µF 400V low profile capacitors

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PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a full kit.* If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects which are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the Silicon Chip OnlineShop has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
HIGH TEMPERATURE THERMOMETER MAIN PCB	MAY 2012	21105121	$20.00
HIGH TEMPERATURE THERMOMETER Front & Rear Panels	MAY 2012	21105122/3	$20.00 per set
MIX-ITT 4 CHANNEL MIXER	JUNE 2012	01106121	$20.00
PIC/AVR PROGRAMMING ADAPTOR BOARD	JUNE 2012	24105121	$30.00
CRAZY CRICKET/FREAKY FROG	JUNE 2012	08109121	$10.00
CAPACITANCE DECADE BOX	JULY 2012	04106121	$20.00
CAPACITANCE DECADE BOX PANEL/LID	JULY 2012	04106122	$20.00
WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$20.00
WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD	JULY 2012	05106122	$10.00
SOFT STARTER FOR POWER TOOLS	JULY 2012	10107121	$10.00
DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	04108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	25108121	$20.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	07109113	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110121	$20 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	15102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
POD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMS	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$30.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept'11])	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	07112131	$10.00
PORTAPAL-D MAIN BOARD	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
LI1 Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	11104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (DI-) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PLASMOTAN POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TOP.DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$20.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7. 50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
8-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
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TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$5.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60HZ TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
1000B STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
NEW THIS MONTH			
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EMI from DC/DC converters

I am having a hard time finding a commercial DC-to-DC converter that doesn't produce electromagnetic interference (EMI). I have one of Powertech's open frame switchmode power supplies (on page 263 of Jaycar's 2016 catalog). Mine is a 240VAC to 12V DC unit. Using it as a power source for a remote-controlled relay I get no EMI and a good range for the relay. I get the same result with a linear voltage regulator.

I also have a very small boost converter which I use to convert 7.2V DC to 12V DC to run the remote relay. This is just a few components laid out on a PCB. It works perfectly for converting these voltages but interferes with the remote relay operation.

I have been told that these are called open-frame switchmode power supplies (SMPS). This is a bit odd because the Powertech models are also called open-frame, even though they are enclosed in a metal case.

Anyway, to get to the main point. Why is it that I can get a 240VAC to 12V DC SMPS which is EMI-free but I can't find a DC-to-DC converter that is EMI-free? Are these commercially available or not? I haven't the time or inclination to learn all the RFI methods such as filters, ground planes, etc.

Page 264 of the 2016 Jaycar catalog features a 6-12V DC input to 11-26V DC output boost converter. This is in a plastic case with a metal base. I doubt that this is a heatsink because the output current is only 2A. Is that a ground plane?

Anyway, the technician at Jaycar cannot tell me if this is going to be EMI-free. Have any of your readers used these modules? Also, they may be able to tell me where I can get an EMI-free DC-to-DC converter. I have no interest in building my own. (P. C., Boulder, WA).

- We cannot give you a definitive answer but since we have yet to see a switchmode supply which is EMI-free and since the definition of "EMI-free" is probably subject to all sorts of interpretation, we think that such a beast is extremely rare. On the other hand, since you say an open frame power supply works, that suggests your device will tolerate a small amount of EMI.

Also, note that there are two different types of "noise" which a power supply could produce that may upset your remote relay – electromagnetic radiation (ie, EMI) which could "drown out" or otherwise interfere with the radio signal it produces, and ripple/hash superimposed on the output voltage which could interfere directly with the circuit operation. The latter seems more likely to be the culprit in your case and this is much more easily filtered out.

Our usual approach when driving sensitive circuitry from a DC/DC converter is to use a converter which produces a slightly higher voltage than required, followed by a linear regulator which filters out most of the switching hash. Use a low-dropout regulator if high efficiency is required. Generous input bypass and output filter capacitance helps, especially using low-ESR capacitors. We can't suggest a particular model of DC/DC converter as we would have to buy it and test it to find out what its EMI performance is like.

The CLASSiC-D as a bass practice amplifier

I have a query regarding the CLASSiC-D amplifier. I want to use this as a bass guitar power amplifier. I currently have a 15W practice amp with headphone jack which I was considering using in conjunction with the CLASSiC-D. What would be the best way to connect to the CLASSiC-D, using the headphone jack or speaker output from the practice amp? Or are these flawed approaches? (P. B., via email.)

- More than likely, the headphone output will have a low level that may be suitable for the CLASSiC-D input. You may need to add a volume control

CDI Module For Outboard Motor

I purchased a KC5466 CDI Module kit from Jaycar which was originally presented in the May 2008 issue of SILICON CHIP. Whilst my old outboard motor ignition uses a CDI system, it does not have a coil trigger to send a trigger signal to the module but a set of points that are purely mechanical switches, so they do not spark as such but merely provide a signal to the ignition system.

Can I adapt the CDI system to work with this motor?

My other question is: the instructions advise power to be directly from the generator coil on the flywheel. Does this mean that I take that source from before the rectifier as post-rectifier, the output is just over 12V DC, not AC? (A. W., via email.)

- The module you purchased was designed to suit engines that had a high-voltage generator and separate voltage trigger. Your engine uses a CDI system that generates its own high voltage and is triggered by points.

Either of the following two projects below would suit your engine, assuming you have a 12V battery supply for powering the ignition:

(1) High-Energy Multi-Spark CDI For Performance Cars (December 2014, January 2015): **www.siliconchip.com.au/Issue/2014/December/High-Energy+Multi-Spark+CDI+For+Performance+Cars**

(2) High-Energy Ignition System for Cars (November-December 2012; Jaycar kit KC5513, Altronics kit K4030): **www.siliconchip.com.au/Issue/2012/November/High-Energy+Ignition+System+for+Cars%2C+Pt.1**

potentiometer of say 10kΩ between the headphone output and the CLASSiC-D input to set the signal level, ie, connect the anti-clockwise terminal end to ground, the clockwise end to the headphone output and the wiper to the CLASSiC-D input.

Check that the headphone output does not have a DC voltage that may indicate the 15W amplifier drives the headphones in bridged mode. In this case, a 100µF capacitor (positive to the headphone output) could be used to couple to the volume potentiometer.

Problems with Barking Dog Blaster

I have recently constructed this kit from Altronics (K4500) and have had some issues with it. Initially, its operation seemed unsuccessful in giving neighbouring dogs an unpleasant feeling and deterring their barking. They are within 15m of the tweeter box. After getting the assistance of a friend with an oscilloscope, we found that one of the Mosfets was not functioning, so both were replaced with the same type. There was no improvement in the deterrent effect.

We then found there was no resonance occurring on the output, so the scope trace was a real mess. On checking the 39-turn inductor, it measured only ~160µH instead of the 200µH quoted as necessary. We had to add another four turns of wire to achieve the required inductance, even though all turns appeared to be fairly tightly wound on the core. The scope trace then appeared to be as shown in the instructions. However, there still seems to be no improvement as a deterrent.

All wiring, solder joints, components and connections have been checked again. It is powered by a 12V battery from an electric start lawn mower, so there is plenty of capacity.

I made a recording of the test tone which is at a reasonable volume and can be heard at least 25m away. It is not a constant frequency and the variable tone repeats over a period of several seconds. This does not seem consistent with your description of a tone at 1.5kHz.

I also made a recording of the ultrasonic tone which is at a very low volume and difficult to hear. This was recorded at the lowest frequency setting, ie, with trimpot VR1 set fully anticlockwise and hence a frequency of below 20kHz. During the adjustment process, there is never any sign of an audible tone (apart from clicking), even with VR1 fully anticlockwise. The faint

Varying Pool Pump Motor Speed

I'm just starting to build the 1.5kW Induction Motor Speed Controller, first published in the April 2012 issue of SILICON CHIP. I intend to use the controller in pool pump mode on my swimming pool pump motor.

About once a week I engage a "crawler" suction device in the pool and suspect that I might need the pool pump to operate at full power for this device to work properly. Can you recommend a way to easily switch between pool mode and full power?

I will have the controller on the opposite side of a wall to the pump and timer unit, so plugging/unplugging the supply and motor would be a real nuisance.

Maybe the pool DIP switch could be brought out to a toggle switch and labelled something appropriate like "crawler" and "normal" for its two positions.

I would guess that the software reads the DIP switch at power up and no harm would be done if the "pool" switch was changed while the motor was running. If this guess is correct, I would expect to turn power off to the controller, change the switch position and then power up again to alter the mode of operation. Is my idea OK or can you suggest a better way? (M. H., Moonee Beach, NSW.)

- You have worked out the obvious approach and there should be no problems with it.

Radio, Television & Hobbies: the COMPLETE archive on DVD

This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

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Using the Micromite on a Mac

I love your magazine though I find many of the projects not to my taste. I am new to this technology and find it quite daunting that while my MacBook that has a native terminal app, no one seems to be able to help with connection to or programming a Micromite. I have tried the forums, no help there. I bought the Micromite LCD BackPack and have not been able to use it; it has been nothing more than a table ornament.

I don't ever want to buy a Windows computer nor do want to taint my Mac with Windows. Macs are Linux-based so I really don't see why Macs are shunned so much.

Also, why are we still playing with serial port? Can't we have direct USB or IP through a Ethernet connection? Honestly, serial is soo yesteryear! (S. H., Garfield, Vic.)

● Yes, the Macintosh family is often left out, perhaps because Macintosh users do not seem to be active in this area. It is not hard to connect to the Micromite LCD BackPack and the Macintosh OS has the required drivers and terminal emulator built-in but we suspect that you are looking for a detailed step-by-step tutorial and we cannot help you there.

The best place to ask these questions would be on Macintosh forums or the Back Shed Forum (**www.thebackshed.com/forum/Microcontrollers**) where there could be some Mac users who might be able to help.

The Micromite uses a serial interface because it is simple and works well. The Micromite is intended to be an embedded controller and implementing a full Ethernet interface on that would be very complex and consume most of the microcontroller's resources, leaving nothing for your BASIC program. It would also increase the cost quite a bit.

clicking sound can only be heard up to maybe 50cm from the tweeters, certainly not the few metres suggested in the introduction to the kit article.

Just three days ago, on pressing Start (via a remote), I could hear the test tone sounding from a distance of about 25m. Maybe this was a one-off glitch or it may have happened previously without me hearing the tone from inside the house. This also seems to indicate a problem somewhere.

These factors make me think there could be a problem with the programming in the microcontroller chip which is limiting the ultrasonic output in the same way as the audible test tone is reduced in volume. Maybe there are some other factors that may influence the operation of the kit. Your comments and assistance in resolving any problems, or other test procedures would be greatly appreciated.

In the Altronics kit, the original Mosfets (STP30NE06L) were substituted with STP36NF06L. When replacing the Mosfets as mentioned above, I was offered STP36NF06 (not the L version) as a replacement from a smaller electronics shop. They were said to be the same and would do the job. Is this correct, and can you explain the difference between these two versions? I find it difficult to interpret some of the details in the data sheets. (B. M., via email.)

● The test tone is there just to verify that there is sound being produced. It is not meant to be a constant fixed frequency; just one that is audible. The output level of the test tone is deliberately reduced so that it is not loud.

However, the ultrasonic tone bursts are at full volume even though inaudible to (most) humans even with the adjustment set for just under 20kHz. Any sound that can be heard from the tweeters when producing the tone bursts are just artefacts of how the tone is produced, with slight clicks at the onset and switch-off of each burst. Be rest assured that the actual ultrasonic sound level is very high.

The switching from ultrasonic bursts to the audible tone is achieved by having the start switch contacts or CON1 connections closed at power up. This is what would have caused your Barking Dog Blaster to have switched to the audible tone with the remote control essentially closing the connection. You can restore to the ultrasonic burst by having the CON1 connections closed at power up again to switch operation back.

The STP36NF06 is not a logic-level Mosfet (ie, one that is suitable for switching using a 5V level at the Mosfet gate). Use the correct L version that allows the gate to be driven to around 5V and provide a low drain to source resistance. Otherwise, the output may be weak or non-existent. The Mosfet you have used is very similar to the part we specified and should work OK.

If you get the waveform as shown in Scope 1, then the ultrasonic bursts are being produced. You should get a higher level when using the correct logic level Mosfets.

We cannot guarantee that every dog will respond to the ultrasonic bursts, as detailed on pages 30 and 31 of the September 2012 issue.

Motor speed controller too heavily loaded

I have a 1.85kW single-phase induction motor which I need to speed control. Its name-plate rating is 2880 RPM. I purchased one of your 1.5kW Induction Motor Speed Controller kits from Jaycar some time ago, however, when I connected it to my motor driving a load, it blew a significant number of components on the PCB. Rather than work out what components should be replaced, I purchased another kit, assembled it and then blew it up under the same conditions.

I should say that initial testing with the unloaded motor on both speed controllers actually worked OK but when I set it up with the motor driving my experimental load, that is when catastrophe struck.

My experimental load is a generator which has two rotors of one metre diameter and each weighing 1kg. When I attempted to drive this generator with my motor, it only reached about 500 RPM (my estimate) before it tripped the circuit breakers in my house. I was hoping that the speed controller would solve that problem by letting the speed build up gradually. Can you help me? (W. Z., via email).

● Well, there are a number of problems to address. The first is that the Induction Motor Speed Controller (SILICON CHIP, April, May & December 2012) is rated to drive motors up to 1.5kW, not 1.85kW although it would probably handle a lightly loaded induction motor of 2kW or more without problems.

Your attempt to use your motor (without a speed controller) to drive your load and the fact that the motor has only reached about 500 RPM suggests that it was drawing a very high current at the time it tripped the circuit breakers. This is normal for an

SAD

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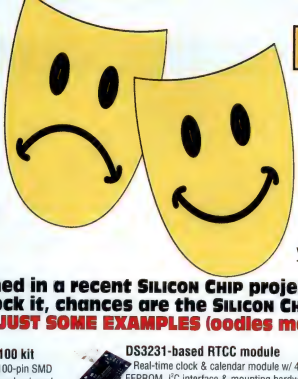

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Detecting Wiring Voltage Drop With Voltage Switch

I have a 2001 Mazda T4600 light truck (Winnebago Motor Home). I am trying to install driving lights but am having difficulty figuring out how to add a relay into the circuit because of the parallel earth battery switching. Could I use the Threshold Voltage Switch from the July 2014 issue to sense the voltage drop across the high beam supply leads to activate a relay for switching the driving lights? Would the circuit react fast enough to avoid problems at switch-off? (B. H., Orange, NSW.)

● Yes, you could use the Threshold Voltage Switch to detect the voltage drop in the leads to the battery. The switching threshold can be adjusted to near 0V, but would need to be at least say 30mV to provide sufficient hysteresis. Presumably, you would be detecting a drop of over 100mV when the high beam is on. Adjust the hysteresis (VR2) close to maximum so the Threshold Voltage Switch will switch on and off reliably with such a low threshold. Leave LK1 open.

The response time may be too slow due to the 1µF electrolytic capacitor at pin 2 of IC1a. This can be changed to a 100nF MKT polyester type to give a response time of less than 100ms.

induction motor as it will draw very high currents until it reaches close to its rated speed. In a typical loaded situation, such as when driving a swimming pool pump, the motor will only draw the high currents for a few seconds and that won't cause problems.

Clearly, your experimental generator is too heavy a load for your motor and the combination is far too heavy a load for the Induction Motor Speed Controller.

6-digit LED Clock dimming settings

I built the 6-digit GPS clock from December 2015 and calibrated the LDR as per the instructions, using a torch shone onto the LDR. The problem now is when the clock is in an artificially lit room (lights on in the evening) the display is dimmer than what I would like, as the ambient light level in the room isn't as bright as a torch!

Before I calibrated the LDR, the display was at 100% brightness in an artificially lit room and dimmed down when the lights were turned off (total darkness). I want to reset the clock back to this state. I have tried discharging the back-up capacitor and also removing the PIC micro from the board for five minutes but it would appear this calibration is permanently written to the chip. How do I reset this back to default?

● Try setting the LDR upper limit %, lower limit % and minimum display brightness via the options menu – see Fig.9 on page 41 of the January 2016 issue and item (4) on page 43 of the same issue, under the "Changing options" sub-menu.

There's no way to reset the LDR calibration without re-programming the chip. Ideally you shouldn't have to though since changing those options gives you the same effect. If you still can't get it to work, one possibility may be to adjust the resistance in series with the LDR, to shift the detected brightness value. Increasing this series resistance (eg, replacing the 10kΩ resistor from the 3.3V rail with a 22-100kΩ resistor) will make the unit act like the ambient light is brighter and thus increase the typical display brightness.

Flightradar airport query

I was wondering with your article about plane tracking: what if your airport is not on the list? How do I set my location via a USB dongle? (M.H., via email).

● We assume you are referring to the article "ADS-B and Flightradar24" in the August 2013 issue. The only reason we can see for your local airport not to be on the list is if there are no scheduled airline services to or from it. For example, several towns in country NSW are not listed but have quite sizable airports – all victims of airline cost-cutting (and/or going broke!).

Airports which do have a scheduled service (as distinct from charter or similar) have a blue and white "teardrop" on them. Click on this and you can see arrivals (past and scheduled), departures (ditto) and aircraft on the ground. Flightradar24 has changed a little since that article but the information is essentially the same. Click on a plane image and it will reveal a whole lot of data about that plane and flight.

Some planes with ADS-B will show the airfield of origin (eg, Bankstown NSW - BWU) even if the airfield itself doesn't show up. Incidentally, military airfields which don't also have commercial flights such as Richmond (NSW) do not show up, while Canberra and Newcastle RAAF bases do show up because they also service commercial airlines.

As far as setting your location, there is no setting as such – it doesn't care where YOU are, just the planes! If you use Flightradar24, you can zoom in to any area on the planet (almost down to your own backyard!). On the **www.flightradar24.com** page under the "add coverage" tab you can apply for a receiver from them if your area is seen to be lacking in coverage. Not knowing where you are located, we don't know whether this is the case or not.

Queries on the NiMH Float Charger

I have a few questions about NiMH rechargeable batteries, related to the "Float Charger for NiMH Cells" entry in Circuit Notebook from the June 2010 issue, by David Eather.

It says that VR1 is set for 1.35V per cell. Does that mean that when charging eight cells, VR1 is set to 10.8V? How long would you have to charge the cells, if they were brand new, to bring them to full capacity?

When charging a 9V type (8.4V) NiMH battery, what should the power supply be set at to charge this battery correctly? I would assume just above the 8.4V level, say, 8.7V.

Finally, a general question about NiMH batteries: how long should you charge them, five or 15 hours? (R. M., Melville, WA.)

● Since VR1 is set for an output voltage of 1.35V per cell, for eight cells that would be 10.8V. The time to fully charge the cells will depend on the cell capacity, initial state of charge and the charge current. To calculate the time to fully charge completely flat cells, divide the charge current in mA

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Ask SILICON CHIP

. . . continued from page 102

(200-600mA, as set by R1 and R_{CL} from Table 1) into the cell capacity (in mAh) and multiply by 1.5 for the charge time in hours. For example, for 2000mAh cells and a 200mA charging current, 2000mAh / 200mA x 1.5 = 15 hours.

A 9V (8.4V) battery has seven cells so VR1 would be set for 7 x 1.35V = 9.45V at the output. The required input voltage will need to be at least 3V above this to allow for diode D1's forward voltage drop, the dropout voltage of REG1 and the voltage across R1 and R_{CL}. So about 12.5V is required.

Charge time for NiMH batteries can vary as it depends on the charge current. A fast charge is five hours and trickle charge, 15 hours. Cell temperature can rise well above ambient with fast charging so normally, a charger should have temperature monitoring if you want to charge faster than the five hour rate.

Remote Control Extender not working

I built the Infrared Remote Control Extender described in the October 2006 issue around that time and it has given faultless service until now. I recently upgraded to the Foxtel HD iQ3 system. The extender no longer works. I have operated the frequency pot through its range without result. Every other remote control still keys the LED.

. . . continued on page 104

Could you produce a new version or present changes to component values which will get it working with this remote? (D. V., Kirwans Bridge, Vic.)

- It seems that the Foxtel HD iQ3 remote control is not an infrared system and that is why the Remote Control Extender does not work with it. The HD iQ3 is actually a Bluetooth wireless remote and should work a reasonable distance from the Foxtel receiver when the two are paired.

Apparently, the remote control from the iQ2 system is compatible with the iQ3 receiver and you can possibly use an iQ2 remote with the Remote Control Extender instead.

Power supply options for the 4-channel mixer

I have been recently reading your article regarding the 4-channel mixer kit and have a question regarding power. This new version has replaced the old version which had ±15V power rails and therefore could run off the power supply of a preamplifier. With the new kit only running from 12V DC, what can I do if I want to run it off the ±15V power rails in an amplifier? (M.M., via email.)

- We assume that you are referring to the June 2007 4-channel mixer that runs from a single 12V supply. The June 2012 Mix-It! 4-channel mixer can use a ±15V or +15V supply (or various other combinations including higher and lower voltages and AC input). The June 2007 4-channel mixer can be run from a 15V DC supply without any changes to the circuit, so you could run it off say the positive amplifier supply rail and ignore the negative rail. Its maximum supply input is 16V. SC

Notes & Errata

50A Battery Charger Controller, November 2016: the Online Shop (page 80) shows the microcontroller as a PIC16F88; it should be a PIC12F675 (the parts list is correct).

WiFi Switch Control Using a Raspberry Pi & Smartphone, November 2016: a revised version of the script (v2) is now available which has two improvements. Firstly, it shows the current state for all outputs, rather than the most recently changed output. Secondly, if URLs stored in browser history are accessed, they will no longer repeat previous actions (ie, turn outputs on/off or pulse).

Precision Voltage & Current Reference with Touchscreen Control, October 2016: Fig.1 on page 74 shows a resistor with a value of R+12 as part of the Programmable Gain Amplifier and the gain is shown as being 1-20 times. In fact, this resistor value should be shown as R+8 and the gain range is 1-15, giving a maximum VREF of 37.5V. The panel at the top of page 79 is also incorrect; again, the 1.5kΩ resistor is 1/8 the ladder resistor value of 12kΩ (not 1kΩ and 1/12 respectively, as stated).

Next Issue

The January 2017 issue is due on sale in newsagents by Monday January 2nd. Expect postal delivery of subscription copies in Australia between December 29th and January 13th.

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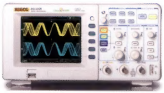

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- Hardened and precision ground

SIZE			
2MT	$99	~~$108.90~~	(C062)
3MT	$109	~~$121.00~~	(C063)

3-Piece Universal Milling Kit

- 12mm & 16mm end mills
- 50mm face mill
- 1 Pkt (10) of inserts

$275 ~~$302.50~~ (M530)

Lathe Turning Tool Kit

- Right and left hand turning tools
- Boring bar
- 1 Pkt (10) of inserts

SIZE			
12mm	$259	~~$290.40~~	(L450)
16mm	$286	~~$314.60~~	(L451)

Slot Drill & End Mill Sets

- 12 piece sets
- HSS Tinite coated
- Metric: 4-12mm
- Imperial: 3/16" - 1/2"

TYPE			
Metric	$75	~~$84.70~~	(M333)
Imperial	$75	~~$84.70~~	(M335)

EF-5S Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes carry case

$35 ~~$42.35~~ (F100)

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- JAMES
Staff Member

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Specifications & Prices are subject to change without notification. All prices include GST and valid until 31-12-16